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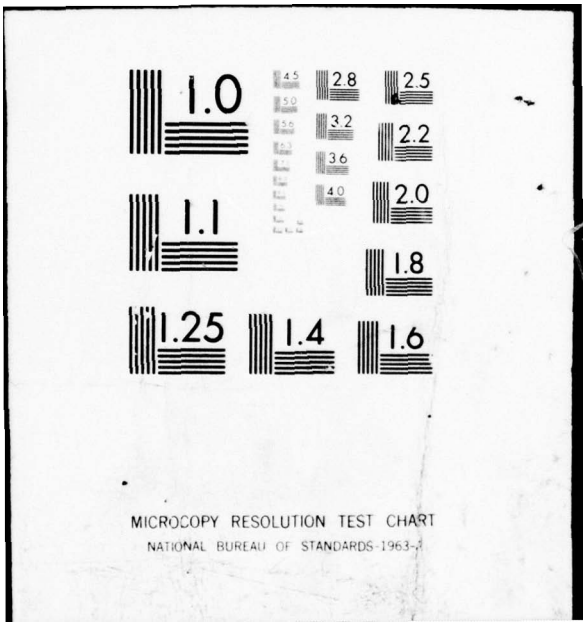
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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TEST AND EVALUATION FOR AN

AIR-LAUNCHED GUIDED MISSILE PROGRAM

by

Kennerly Wendell Funk and Richard Loraine

December 1977

Thesis Advisor: M. B. Kline

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This thesis evaluates the Navy's test and evaluation (T&E) process for air-launched guided missiles, identifies T&E management problems, and proposes utilization of a particular test program strategy. Many changes have been made to improve the T&E process, but some of these have resulted in costly inefficiencies. Contributing problems include: the operational test agencies do not participate adequately in early test planning, excess duplication exists in testing done by major

participants in the Navy air-launched guided missile T&E process, lack of definition of a mission profile leads to improper and inadequate testing of air-launched guided missiles, and numerous other T&E management problems.

The utilization of an Integrated Test Program approach for air-launched guided missile T&E is proposed. Test data from contractor demonstration tests, limited TECHEVAL, and OPEVAL would be pooled to confirm compliance with specification requirements and verify operational effectiveness and suitability. Test assets and other resources would be conserved and overall T&E schedule improved.

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Test and Evaluation for an Air-Launched Guided Missile Program

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ABSTRACT

This thesis evaluates the Navy's test and evaluation (T&E) process for air-launched guided missiles, identifies T&E management problems, and proposes utilization of a particular test program strategy. Many changes have been made to improve the T&E process, but some of these have resulted in costly inefficiencies. Contributing problems include: the operational test agencies do not participate adequately in early test planning, excess duplication exists in testing done by major participants in the Navy air-launched guided missile T&E process, lack of definition of a mission profile leads to improper and inadequate testing of air-launched guided missiles, and numerous other T&E management problems.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACAT	-	Acquisition Category
ALGM	-	Air Launched Guided Missile
ASN(R&D)	-	Assistant Secretary of the Navy for Research and Development
CDT	-	Contractor Demonstration Tests
CNM	-	Chief of Naval Material
CNO	-	Chief of Naval Operations
COMOPTEVFOR	-	Commander, Operational Test and Evaluation Force
DCNO	-	Deputy Chief of Naval Operations
DCP	-	Decision Coordinating Paper
DDR&E	-	Director of Defense Research and Engineering
DD(T&E)	-	Deputy Director of Defense Research and Engineering, Test and Evaluation
DMSO	-	*Director, Major Staff Office*
DOD	-	Department of Defense
DODD	-	Department of Defense Directive
DPT	-	Design Proof Tests
DSARC	-	Defense System Acquisition Review Council
DT	-	Development Test
DT&E	-	Development Test and Evaluation
EET	-	Environmental Evaluation Tests
EMC	-	Electromagnetic Compatibility
FACI	-	First Article Configuration
FOT&E	-	Follow-on Operational Test and Evaluation
GSE	-	Ground Support Equipment
IOC	-	Initial Operational Capability
IOT&E	-	Initial Operational Test and Evaluation

MRTFB	-	Major Ranges and Test Facilities Base
MTBF	-	Mean Time Between Failure
NATC	-	Naval Air Test Center, Patuxent River, Maryland
NAVAIR	-	Naval Air Systems Command
NAVMAT	-	Naval Material Command
NAVSEA	-	Naval Sea Systems Command
NEODF	-	Naval Explosive Ordnance Disposal Facility, Indian Head, Maryland
NMARC	-	Navy Marine Corps Acquisition Review Committee
NOMTF	-	Naval Ordnance Missile Test Facility, White Sands, New Mexico
NWC	-	Naval Weapons Center, China Lake, California
NWL	-	Naval Weapons Laboratory, Dahlgren, Virginia
OPEVAL	-	Operational Evaluation
OPNAV	-	Offices of the Chief of Naval Operations
OPNAVINST	-	Office of the Chief of Naval Operations Instruction
OPTEVFOR	-	Operational Test and Evaluation Force
OSD	-	Offices of the Secretary of Defense
OT	-	Operational Test
OT&E	-	Operational Test and Evaluation
PAT&E	-	Production Acceptance Test and Evaluation
PGSE	-	Peculiar Ground Support Equipment
PMA	-	Program Manager Air
PMTC	-	Pacific Missile Test Center, Point Mugu, California
QT	-	Qualification Tests
R&D	-	Research and Development
RDT&E	-	Research, Development, Test and Evaluation
SECDEF	-	Secretary of Defense

SECNAV	-	Secretary of the Navy
TAAF	-	Test Analyze and Fix
T&E	-	Test and Evaluation
TECHEVAL	-	Technical Evaluation
TEMP	-	Test and Evaluation Master Plan
VX	-	Air Test and Evaluation Squadron

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In this thesis comments not specifically identified with a particular interviewee should only be taken as the authors' interpretation of the consensus of opinions from the agencies with whom interviews were conducted. Any inaccuracies which might appear are the sole responsibility of its authors and result either from a misinterpretation or lack of information.

I. INTRODUCTION

A. BACKGROUND

The acquisition process for defense weapon systems came under intense criticism in the late 1960s and early 1970s because of costly development overruns, schedule slippage, and system performance shortcomings. The President's Blue Ribbon Defense Panel, the General Accounting Office, the Congress's Commission on Government Procurement, and the Armed Services Committees of the House of Representatives and Senate have consistently identified test and evaluation as a major problem area. The Department of Defense (DoD) responded to the criticism by issuing new guidelines and directives instituting procedures which put a new perspective on the acquisition process. A major outcome of the new procedures was the increased emphasis of test and evaluation (T&E). Of concern was the fact that T&E had not commanded the importance, stature, or priority that it must have if it is to be a primary source of information on the progress of major defense systems and for decision-making.

As a result, the new directives stated that T&E will commence as early as possible and be conducted throughout the system acquisition process, and that program schedules and milestone decisions will be based upon accomplishment and assessment of the program's T&E efforts. Also implemented was the establishment of a T&E organization in the Offices of the Secretary of Defense (OSD) to oversee defense T&E activities. It was further required that a primary role would be played by independent test agencies within DoD components in the accomplishment of T&E [Refs. 1 and 2].

Implementation of the guidelines and directives has encountered some difficulties. T&E is costly, difficult, and time consuming. There are many people involved and genuine competition exists within DoD between agencies, between DoD agencies and contractors, and between contractors for scarce defense dollars.

However, the value of T&E cannot be overlooked. In a recent overview statement to Congress, the Deputy Director (Test and Evaluation) of the Office of Defense Research and Engineering said that T&E was a good investment from which essential information was obtained to effectively manage the research, development, and procurement of defense systems. By insuring that only proven, fully-effective weapon systems are deployed, T&E allows us to obtain maximum military capability for our defense dollars [Ref. 3].

B. PURPOSE AND OBJECTIVES

The purpose of this thesis is to examine the management policy of T&E during this new era of T&E emphasis and some of its associated problem areas, and then to relate the policy and problems to an Air Launched Guided Missile (ALGM) program.

The primary objective of the thesis is to provide guidance for an optimizing test strategy for T&E of ALGM programs to be used by the program manager in his management duties. In addition to providing a test strategy, the thesis is intended to be a self-contained document wherein the ALGM program manager has the T&E policy, requirements, instructions, organizations, facilities, potential problem areas, testing requirements and typical test program scope identified. This should help the program manager resolve some of the T&E management issues and help him avoid some of the problems inherent in the T&E

efforts. The test strategy will aid the program manager in the budgeting process, in his early program planning, in bringing T&E issues into focus, and will serve as a source material in preparation of such program documents as Decision Coordinating Papers and Test and Evaluation Master Plans.

C. SCOPE

The thesis addresses T&E from general policy within DoD to Navy application and specific Navy ALGM program implementation. By the nature of the subject matter (management of T&E), many of the management issues and problems are broadly applicable and relate to the total spectrum of T&E. However, the subject can be applied equally to ALGM defense weapon systems.

The thesis investigates management of T&E in reference to Navy Acquisition Category I and II ALGM programs.[1] The program life cycle period addressed is from program initiation through release to production (that period covered by Research, Development, Test and Evaluation (RDT&E) funding).

An Air-Launched Guided Missile system may be a constituent of a larger defense weapon system which has as its primary sub-system a missile, aircraft avionics sub-system, and support equipment. The missile is dominant in the system and is in the center of most T&E activity. The missile is constructed of sections, these typically being guidance, control, warhead and propulsion. Within each missile

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[1] The Navy Acquisition Categories (ACAT) are defined in reference 4. ACAT I is for systems with dollar thresholds of $75 M RDT&E and $300 M production, and ACAT II have $20 M RDT&E and $50 M production thresholds.

section are components, assemblies, and parts. ALGMs currently within the Navy inventory are comprised of two broad categories or groups, air-to-air and air-to-surface. Typical within the air-to-air group are Sidewinder, Sparrow, and Phoenix. The air-to-surface group includes Condor, Shrike, Standard Arm, and HARM.

D. ISSUES

The major issue addressed in this thesis is how can T&E be managed effectively and efficiently for ALGM programs. Related issues include whether there is an optimal test strategy which minimizes proliferation of requirements, resources, and facilities, yet provides resolution to development test questions and provides significant and relevant information to support milestone decisions. Also, can the problems inherent to T&E be reduced by implementation and procedural changes or adjustments? Specific areas of interest include: what T&E is required, desired, and affordable; who performs the T&E and when is it accomplished; what is the best approach to implement to satisfy the ALGM T&E requirements, yet is within program dollar and schedule constraints?

These and similar issues relating to the management of an ALGM program's T&E activities are continually addressed in the thesis and potential solutions are explored.

E. RESEARCH METHOD

A data and literature search was performed initially, and all pertinent DoD directives, Navy instructions, and other T&E guidelines reviewed. T&E facilities and organizations which might have a role in an ALGM program were examined.

Interviews were conducted with participants in ALGM T&E efforts (Appendix A), both those in upper level management and review cycles

and those who directly implement program T&E activities. Activities interviewed include:

1. Deputy Director of Defense Research and Engineering, Test and Evaluation (DD(T&E))
2. Offices of the Chief of Naval Operations (OPNAV)
3. Naval Material Command (NAVMAT)
4. Naval Air Systems Command (NAVAIR)
5. Operational Test and Evaluation Force (OPTEVFOR)
6. Navy Laboratories
7. Participating Field Activities
8. Development Contractors

II. TEST AND EVALUATION AND THE SYSTEM LIFE CYCLE

A. NATURE AND PURPOSE OF T&E

The terms "test" and "evaluation" symbolize distinguishable functions in the RDT&E process. "Test" denotes the actual testing of hardware/software (models, prototypes, production equipment, computer programs) to obtain data valuable in developing new capabilities, managing the developing activities, or making decisions at program milestones or on the allocation of resources. "Evaluation" denotes the process whereby the information content in the data is logically assembled and analyzed to aid in making systematic decisions. In a broad sense, T&E may be defined as the physical testing, experimentation and analyses performed during the course of research, development, introduction and employment of a weapon system or sub-system, and the analytical or evaluative studies performed using the data generated [Ref. 5].

T&E is an integral part of all phases of the development of systems and equipments and provides information for a number of purposes and several different classes of information users. T&E provides the following to the users and developers of systems;

1. Information for development
2. Information for acquisition milestone decisions
3. Information for effective operational utilization
4. Information for assessment of acquisition risks

These are discussed briefly.

1. Information for Development

Testing of systems under development is an inherent part of the Research and Development (R&D) process through which technical

deficiencies and uncertainties, as well as design and operation problems are identified and resolved. This testing provides design data feedback to the developing agency and development contractors. The data feedback is also useful in the design-test-evaluate-redesign process which is basic to the development of reliable systems [Ref. 5].

2. Information for Acquisition Milestone Decisions

The major milestone decisions in the development of a system, to initiate advanced development, conduct full-scale development, and produce a system, are by nature investment decisions. The issue at these milestone decision points is whether initiating or continuing the acquisition will result in the most productive use of the resources (money, material, and personnel). T&E helps provide the basis for these decisions, and the best information possible must be obtained to aid the decision process. In DoD Directive 5000.3 the statement is made that the basis for decisions to commit added resources to a program shall be successful accomplishment of the T&E objectives [Refs. 5 and 6].

The Deputy Director (Test and Evaluation), Office of the Director of Defense Research and Engineering, in his overview statement to Congress in March 1977, stated that the primary purpose of T&E is to provide information for program-level decision making. Two important questions addressed, using T&E information as a basis, are "How well current objectives are being met and what is likely to be the ultimate outcome of the program." Note, one question deals with the past and the other with the future [Ref. 3].

3. Information for Effective Operational Utilization

Information obtained both through development and operational testing provides a valuable data base to the operational user. Typical

is data obtained by the exploration of the performance envelopes of the system. With this information, tactics can be developed and doctrine established for the most effective utilization of the system.

4. Information for Assessment of Acquisition Risks

Unfortunately, many times T&E does not provide information which leads to clear-cut decisions. The T&E information does, however, provide the decision-maker with a means to make judgments and to assess the associated program risks, whether they be technical, managerial, cost or schedule. DoDD 5000.3 states directly that T&E shall be conducted as necessary to provide the information to assess the programs acquisition risks [Ref. 6].

B. DOD POLICY FOR T&E

The current DoD policy for T&E has evolved from the changes and direction initiated in 1969 by David Packard, Deputy Secretary of Defense, when he began to institute reforms in the system acquisition process. Among these reforms was that needs and proposed solutions should be validated, preferably by experimental verification (testing). Mr. Packard proposed early demonstration in areas possessing high development risk, emphasizing T&E as being of paramount importance [Ref. 7]. A study of the major weapon system acquisition process, also in 1969, by a Blue Ribbon Defense Panel established by the President and Secretary of Defense included the subject of T&E [Ref. 8]. This study concentrated, however, on OT&E and essentially found it to be unsatisfactory, recommended changes to make it more effective, and concurred with its significance in the system acquisition process.[2]

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[2]For a more detailed account of this study, as well as other studies on T&E and the role of OT&E in the system acquisition process, see thesis by W. C. Bowes [Ref. 9].

From this study and the implementation of Mr. Packard's philosophy, DoD Directive 5000.1 was issued in 1971 containing requirements for acquisition of major defense systems. Addressing T&E policy, DoDD 5000.1 stated:

> "Test and evaluation shall commence as early as possible. A determination of operational suitability, including logistic support requirements, will be made prior to large-scale production commitments, making use of the most realistic test environment possible and the best representation of the future operational system available. The results of this operational testing will be evaluated and presented to the DSARC at the time of the production decision" [Ref. 1].

DoD then responded with DoD Directive 5000.3 in 1973 [Ref. 2] which contained the requirements for test and evaluation.

A similar statement regarding T&E policy is contained in the January 1977 revision of DoDD 5000.1 [Ref. 10]. Thus this directive provides the basic foundation for T&E as it is implemented today.

DoD Directive 5000.3 establishes the policy for the conduct of test and evaluation by the Military Departments and Defense Agencies (DoD Components) in the acquisition of defense systems. This document contains general policies and principles for T&E. It states that T&E shall be commenced as early as possible and conducted throughout the system acquisition process, and that acquisition schedules will be based upon accomplishing T&E milestones prior to decision-making. Thus the T&E program is planned and executed concurrently with the development phases to support the various users of the T&E information. DoDD 5000.3 covers the requirements for T&E, its function and its role. It also specifies the requirement for the generation of an overall T&E plan and contains procedures and requirements for T&E inputs to the major program review with the Defense System Acquisition Review Council (DSARC) and into the program's Decision Coordinating Paper (DCP). Of

importance to note is that the initial DCP presented to the DSARC at Milestone I will identify the critical questions and areas of risk to be resolved by T&E, and provide test objectives, schedules and milestones. In addition, revised DCPs at later milestones will give results of T&E accomplished to date and update all other T&E areas. The DSARC at major milestones is charged with the responsibility to assess and comment to SECDEF as to the adequacy of the test results to support a decision to proceed with development. The DSARC input on T&E is obtained from the Office of the Deputy Director (Test and Evaluation) whose function is to oversee defense T&E activities and set policy for conduct of T&E [Ref. 6].

DoDD 5000.3 also contains policy for T&E planning in DoD. It states:

> "The DoD Component will prepare as early as possible in the acquisition process, and prior to initiation of Full-Scale Development an overall test and evaluation plan to identify and integrate the effort and schedules of all T&E to be accomplished and to insure that all necessary T&E is accomplished prior to the key decision points. The TEMP (T&E Master Plan) will be kept current by the DoD Component" [Ref. 6].

A significant feature of the T&E policy promulgated by DoDD 5000.1 and 5000.3 is the increased importance and strength of the independent test agency. This evolved in response to the previously cited Blue Ribbon Defense Panel study and was concurred with by the study conducted by the Commission on Government Procurement [Refs. 8 and 11].

C. RELATIONSHIP TO SYSTEM LIFE CYCLE

Figure 1 depicts the system life cycle as adapted from Ref. 7. The process begins with requirements or needs and evolves through the development phases to production and operational use. Figure 2 shows the T&E areas corresponding to the life cycle phase for defense acquisition systems according to T&E types. Also shown are the major program

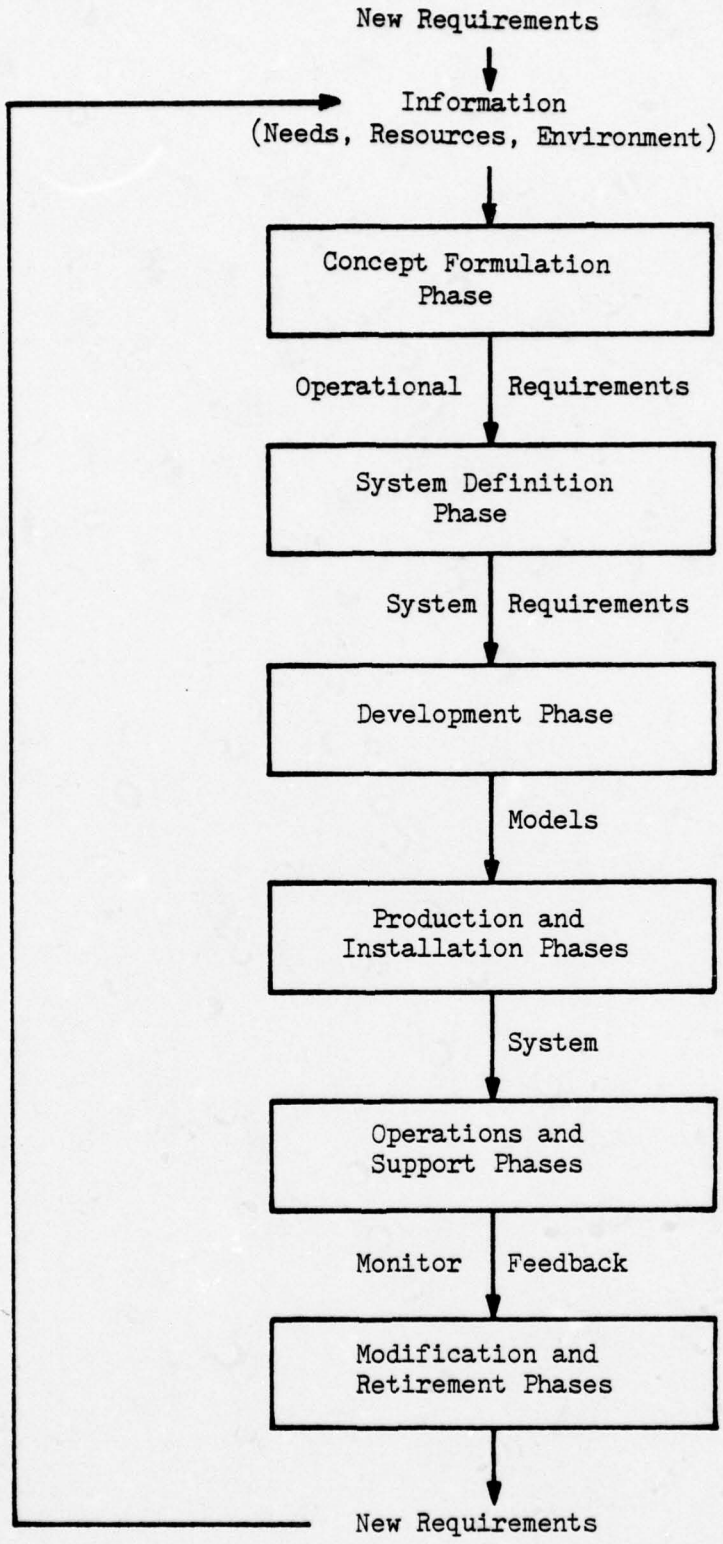

Figure 1. System Life Cycle (Adapted From Ref. 7)

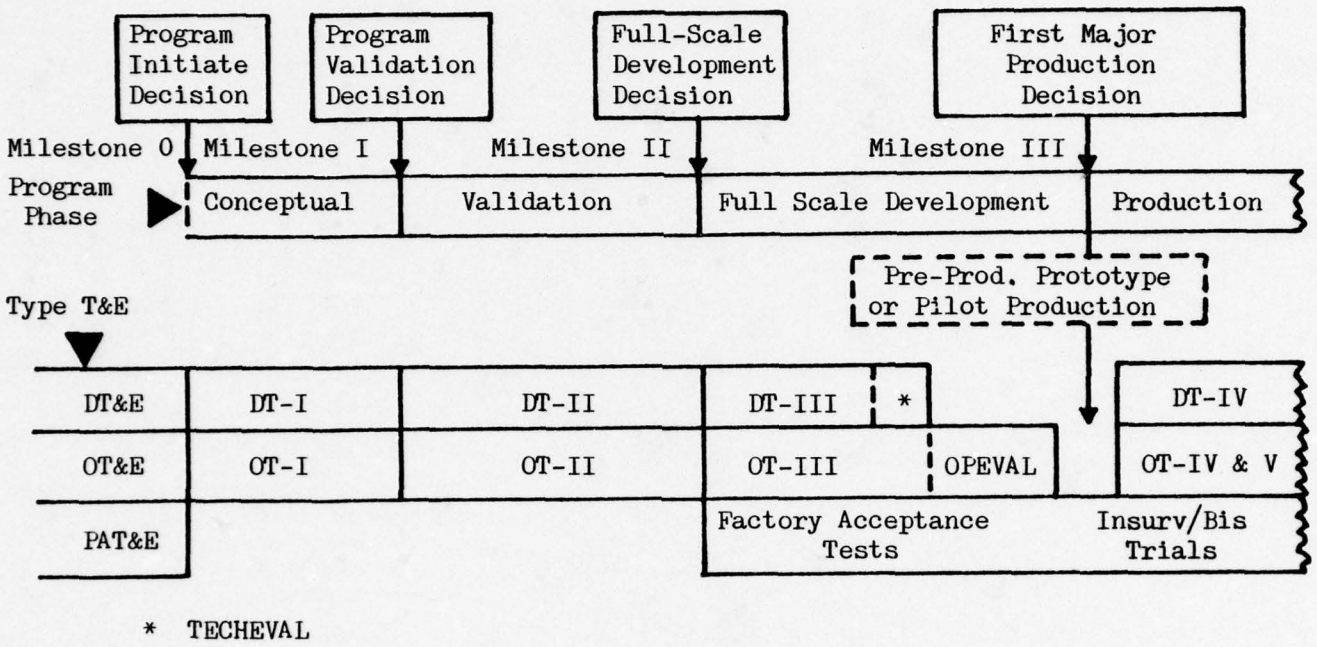

Figure 2. Weapon System Life Cycle and T&E Phases (Ref. 4)

milestone decision points. T&E plays a vital part in Milestones I, II and III. Milestone 0 is the program initiation point where a mission need has been identified and exploration of alternative solutions authorized. Milestone I is the program validation decision point where selected alternatives continue into a demonstration and validation effort. A DCP is required at this time, containing, among other things, identified T&E objectives and issues. Milestone II is the point where a commitment to full-scale development is made for the preferred system. Demonstration and validation of T&E objectives should have been completed and the results should support this decision. The DCP is updated appropriately. Milestone III is the point where the decision is made to produce and deploy the system. T&E makes a major input at this program milestone point [Refs. 4, 10 and 12].

There are three types of T&E used in the system life cycle:

1. Development Test and Evaluation (DT&E)
2. Operational Test and Evaluation (OT&E) which is composed of:
   a. Initial OT&E (IOT&E)
   b. Follow-on OT&E (FOT&E)
3. Production Acceptance Test and Evaluation (PAT&E)

References 4 and 6 describe in detail the three types of T&E. Appendix B contains a brief description of each type for quick reference.

D. PROGRAM REVIEWS

As noted in section II B, a principal purpose of T&E is to provide assistance to decision-makers at program reviews or milestones by providing data and information. Other important program reviews, keyed especially to the commitment of resources, rely much on T&E information. Examples are Congressional reviews with the House and Senate Armed

Services and Appropriations Committees. At these reviews, T&E results, in addition to other program inputs, are used to determine the commitment of funds, program continuation or program alteration. For major programs, reviews occur at various upper management levels throughout the organization, and at which T&E results are vital.

In addition to upper level program reviews, T&E plays an important role in reviews held throughout the system life cycle at the development organization level. Design reviews occur as necessary during the acquisition process, involving the development agency, the development contractor, and the applicable T&E agencies and activities. Testing data and results are an inherent and important part of these reviews, which provide valuable design and development information. Also occurring at the development organization level are periodic reviews of the T&E program to examine test progress and for review of problem identification and resolution information.

III. NAVY TEST AND EVALUATION REQUIREMENTS AND PROGRAM STRUCTURE

This section contains the Navy's implementation of the DoD directives for T&E and, where appropriate, presents unique features relative to ALGM programs.

A. NAVY POLICY FOR T&E

The Navy's most recent implementation response to DoDD 5000.3 was OPNAVINST 3960.10, issued in October 1975, which established the policy for T&E in Navy acquisition programs. This is the principal Navy policy document for T&E. OPNAVINST 3960.10 defines the T&E responsibilities of Navy activities and indicates procedures for planning, conducting, and reporting T&E. It delineates the complementary relationship between DT&E and OT&E, and establishes procedures and format requirements for Test and Evaluation Master Plans (TEMPs) [Ref. 4]. The TEMP is the controlling management document which defines T&E for each acquisition program. OPNAVINST 3960.10 must be understood thoroughly by the program manager, his designee for T&E, and others responsible for implementing T&E policy on a program.

OPNAVINST 3960.10 also clarifies the responsibility of the independent test agency. The agency for the Navy, OPTEVFOR, and its commander, COMOPTEVFOR, has been assigned this responsibility.

The Department of Navy RDT&E Management Guide [Ref. 5] also provides a valuable guideline on management of Navy T&E. Chapter VII and Appendix G of Ref. 5 are devoted totally to Navy T&E and provide appropriate amplification.

B. MANAGEMENT PHILOSOPHY AND ORGANIZATION

The requirement for management of a Navy program's T&E efforts rests primarily with the Program Manager. Even though a broad organization exists in Navy T&E, the Program Manager is responsible for planning, implementing and reporting the T&E for the weapon system. OPNAVINST 3960.10 points out that the Program Manager within the Developing Agency is responsible for development and execution of an adequate T&E program. His T&E responsibilities include defining a test program which illuminates test issues and problems; preparation and updating of the TEMP; and arranging for performance of the required and planned testing and subsequent evaluation [Ref. 4].

In the conduct of the T&E program, however, OPNAVINST 3960.10 delegates authority for the three types of testing to two different organizations. The Developing Agency is responsible for DT&E. For ALGMs, the Developing Agency is also responsible for PAT&E. This includes planning, conducting and reporting. In addition the Developing Agency maintains liaison with COMOPTEVFOR concerning the DT&E program and provides COMOPTEVFOR with appropriate results. For OT&E, the Navy has assigned the responsibility to OPTEVFOR, which is an organization separate and distinct from the developing and procuring command, and from the using command (although attached to CNO). OT&E is planned and conducted by OPTEVFOR, and results are reported directly to the CNO by COMOPTEVFOR. In addition, OPTEVFOR provides the Developing Agency with all significant OT&E results [Ref. 4].

An organizational chart which depicts the Navy's T&E agencies (along with that at the SECDEF level) is shown in Figure 3. It also shows those field activities involved in ALGM program. Descriptions

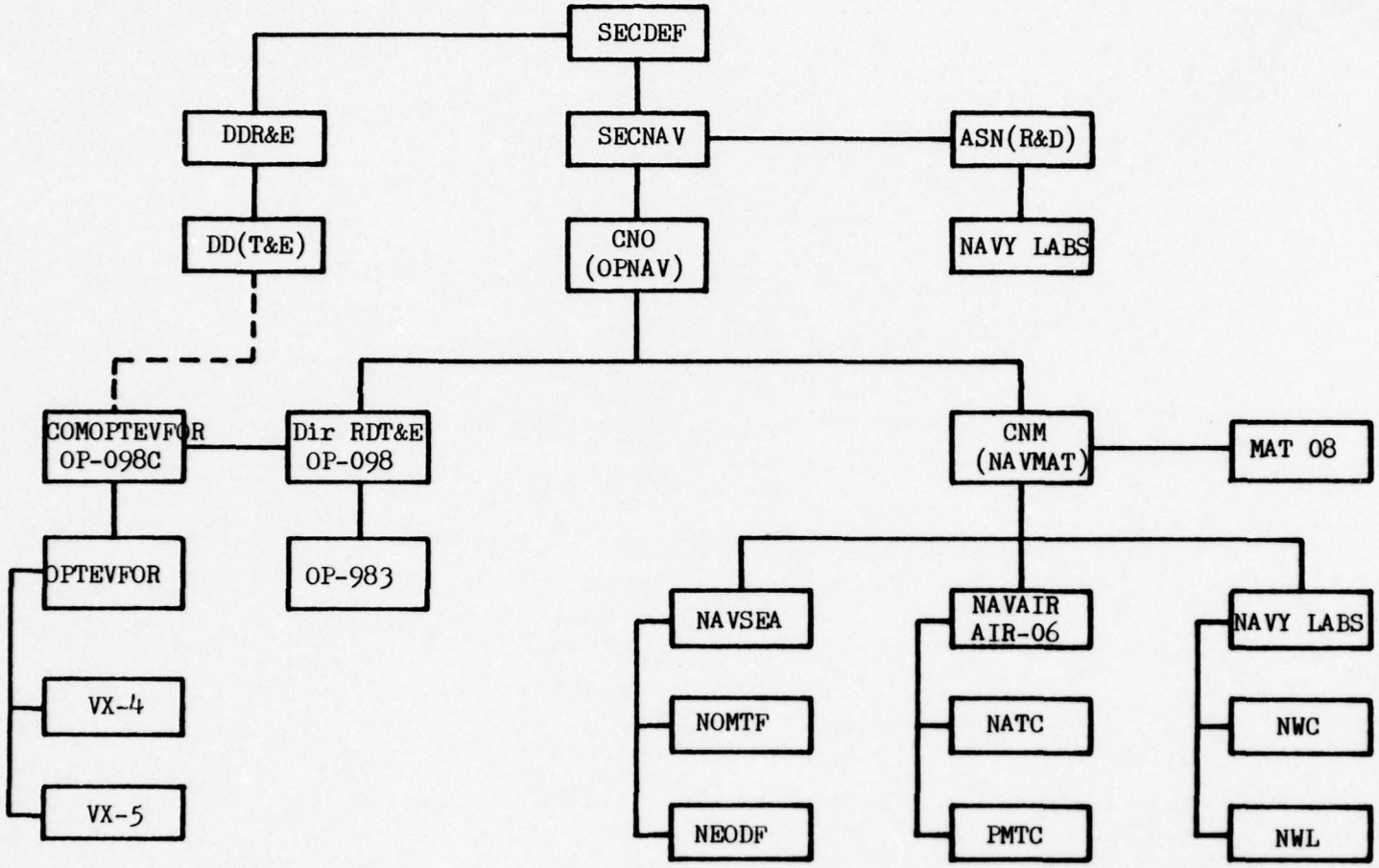

Figure 3. Present Navy T&E Organization Structure for ALGM Systems

of each organization's functions and responsibilities can be found in Ref. 5.

Although complementary, DT&E and OT&E are indeed separate and distinct, both in their basic goals and objectives and in their implementation and conduct. From their requirements foundation, DT&E works to specifications stated in functional or technical terms whereas OT&E attempts to state requirements in operational terms (Appendix B). Thus, their criteria thresholds are generally also different. Many times in DT&E, tests concern only the weapon or a part thereof whereas in OT&E, tests primarily are concerned with the complete weapon system. Another difference is that DT&E often is testing and measuring a specific parameter, holding other things constant to see the effect, whereas in OT&E many times no specific parameter is identified and only an operational environment is created to see what the test results indicate. Thus, repeatability of tests is usually possible in DT&E whereas in OT&E it is not. Further, the people involved in DT&E are usually technical whereas those in OT&E are not technical but operational. RAdm Monroe, former COMOPTEVFOR, addressed these differences in his comments about OT&E stating "that DT&E is a science and OT&E an art, and if there is duplication between the two, T&E is not being properly planned" [Ref. 13].

On paper, the success of a development program's T&E in the Navy rests with the Program Manager. He is responsible for the coordination of the various parts of the T&E effort, including the specific implementation of the many facets of the DT&E program. The program's success is also dependent on the Program Manager's relationship and working procedures with OPTEVFOR, and on his interfaces with organizations

which have Navy T&E responsibilities. In the exercise of his responsibilities, the Program Manager must deal with the contractors, participating field activities, and various testing agencies to implement the DT&E program. He must operate within the matrix organization of the Navy for his technical assistance and support. And he must negotiate with OPTEVFOR to obtain a reasonable and affordable OT&E program, yet meet OT&E requirements. Those in the DT&E program are directly dependent on the Program Manager and OPTEVFOR is indirectly dependent on him as he provides the funds to support both DT&E and most of OT&E. In addition the Program Manager must work with System Command and NAVMAT functional groups on test coordination and facilities planning, and his program must sustain the reviews and scrutinizing of CNO and DD(T&E).

Two especially difficult situations confront the Program Manager in his management responsibility and structure. First, it is the position of DD(T&E) that more value should be placed on OPTEVFOR information for milestone decision-making than on the developing agency's data because OPTEVFOR is an independent test agency. DD(T&E) feels that the developing agency has a vested interest in the program, therefore possesses an advocacy position. Thus DD(T&E) judges data received from DT&E in this light. Bowes made a similar observation in his thesis [Ref. 9].

Second, COMOPTEVFOR is double-hatted, heading-up OPTEVFOR and the T&E division in CNO (OP-983). He also acts as the Assistant Director for OT&E (OP-098C) in support of the Director RDT&E in CNO, reporting from this position directly to the CNO. In the Program Manager's discussions and negotiation with OPTEVFOR, the Program Manager is operating from a potentially difficult position. COMOPTEVFOR's position in the

Navy organizational structure is very powerful compared to that of a Program Manager because of their relative positions with respect to CNO.

C. TYPES AND CATEGORIES OF TESTS

Figure 2 depicted the T&E types and categories of tests. Each of the T&E categories (phases) will be discussed separately as each one possesses unique objectives and features of T&E. Much of the information can be found in OPNAVINST 3960.10. It is presented here because it is continually referred to throughout this thesis.

1. DT&E

a. DT-I

Development contractors and/or participating field activities perform that DT&E possible at this time during the conceptual phase with experimental hardware to demonstrate concepts and feasible approaches to support the program validation decision (Milestone I).

b. DT-II

Development contractors and/or participating field activities conduct this DT&E during the validation phase, normally at the major component/sub-sustem level, to support the full-scale development decision (Milestone II). The hardware is usually of advanced development quality and its purpose is to demonstrate that design risks have been identified and minimized.

c. DT-III

Development contractors design, build, and test engineering development, prototype, and pilot or limited production hardware. They essentially perform design evaluation testing, including redesign and re-test as necessary, to demonstrate compliance with contractual

(specification) requirements. Testing areas include, as a minimum, performance, environmental, reliability/maintainability, compatibility, and safety. Tests are both sub-system and system level (ground, captive and free fight) with environmental evaluation tests, test analyze and fix, design proof tests, and qualification test programs. Reliability and maintainability demonstration programs are also generally conducted.

The Program Manager may designate a participating field activity as the Technical Manager to provide necessary specialized technical and support engineering skills during this hardware development period. In this capacity the participating field activity may witness contractor performed DT&E and may choose to perform (repeat) certain tests judged to be critical to program success. In addition, certain components of ALGMs (e.g., warheads, fuzes, and propulsion systems) are designed, developed and tested by other participating field activities which have special competence, experience, and/or facilities necessary for conduct of these sometimes hazardous development efforts.

Thus, contractually and/or through task assignments to participating field activities, design, analysis, test and evaluation proceeds through DT-III, including formal demonstration and qualification testing, sometimes referred to as Contractor Technical Evaluation or Contractor Demonstration Tests. The final sub-phase of DT-III for most ALGMs consists of subjection to a Navy Technical Evaluation, usually referred to as TECHEVAL. Its purpose is to provide evidence to the Program Manager for certification of readiness for OPEVAL (operational evaluation). The TECHEVALs for ALGMs have historically

been performed for the Program Manager and NAVAIR by a field activity other than the one designated as Technical Manager. This has usually resulted in PMTC, Point Mugu performing this function. TECHEVALs performed by Point Mugu previously have placed significant emphasis on environmental testing in excess of ALGM specification limits and ground and airborne reliability testing to demonstrate compatibility with specification numeric and confidence level requirements. Compliance with maintainability requirements is also evaluated.

DT-III then supports the first major production decision (Milestone III) and demonstrates that the ALGM design meets its specifications in performance, reliability, maintainability, supportability, survivability, system safety, and the totality of elements of electromagnetic vulnerability. In addition, operability, human factors, logistics and system interface compatibility are evaluated.

d. DT-IV

This phase of DT&E is conducted after the first major production decision to verify that product improvements, or correction of design deficiencies discovered during OPEVAL, FOT&E, or fleet employment, are effective.

2. IOT&E

a. OT-I

IOT&E commences early in the program upon the request of the Program Manager with OT-I conducted by OPTEVFOR during the conceptual phase to support the program validation decision (Milestone I). Most acquisition programs do not require OT-I. However, this is the time for OT&E planning to take place.

b. OT-II

OPTEVFOR conducts this phase of IOT&E during the validation phase to provide an early estimate of projected operational effectiveness and suitability of the ALGM, to estimate program progress and initiate development of tactics and finally, to identify operational issues for consideration during the full-scale development phase (OT-III). OPTEVFOR will participate in the ALGM captive flight test program to the extent practicable and may also monitor tests at contractor and participating field activities facilities to aid in performance of its early operational assessment.

c. OT-III

OPTEVFOR conducts this phase of IOT&E during full-scale development to support the program's first major production decision (Milestone III). OT-III concludes with a final sub-phase identified as OPEVAL which normally uses pilot production hardware and begins shortly after TECHEVAL or after incorporation of changes necessary to correct significant problems identified by TECHEVAL. Prior to OPEVAL and availability of pilot production hardware, OPTEVFOR will continue its IOT&E participation in the prototype ALGM evaluation of development hardware with captive flight tests and missile launches according to the program test plan. The purpose of OT-III and particularly OPEVAL is to evaluate ALGM operational effectiveness and suitability (including availability, compatibility, interoperability, reliability, maintainability, human factors, logistic supportability and training requirements) and to continue tactics development.

3. FOT&E

a. OT-IV

OPTEVFOR may conduct this phase of FOT&E after the first major production decision but before production ALGMs are available if hardware problem fixes are to be evaluated, to continue tactics development, or to complete deferred or incomplete IOT&E. This phase may also be utilized for conduct of a fleet reliability evaluation program bv OPTEVFOR (i.e., early introduction and evaluation in actual fleet environment).

b. OT-V

OPTEVFOR conducts this FOT&E on production svstems as soon as they are available. Objectives include demonstration of the achievement of program objectives for production system operational effectiveness and operational suitability, OT&E of the system in new environments, or in new applications, or against new threats.

Figures 4 and 5 show the scope of DT&E and OT&E for ALGMs in a different format. Depicted are test categories and sub-categories for DT&E and OT&E, and typical phases in which the tests are performed.

D. RESPONSIBILITY FOR TESTS

DT&E is planned by, conducted by or for, monitored by, and reported by the developing agency. For ALGM programs, the Program Manager operates from the developing agency organization (NAVAIR) and delegates responsibility to support groups, field activities and contractors for various DT&E tests. The delegation vehicles are task assignments or contracts as appropriate and acceptance by the agencies constitutes obligation.

TEST CATEGORY	TEST SUB-CATEGORY	PHASES
1. Engineering development and design support tests	1. a. Performance tests [Lab (bench), flight line, captive flight, launch and free flight].	DT-I through DT-III.
	b. Integration and compatibility tests.	DT-I, DT-III.
	c. Environmental tests [Environ. survey (mechanical models), environ. shakedowns, environ. evaluation (EET).	DT-I through DT-III.
	d. Reliability tests [Lab (failure) modes tests, rel. growth (test, analyze, and fix TAAF) - Operational (captive flight, launch and free flight)]	DT-II, DT-III.
2. Components/parts qualification tests	2. Critical component and non-standard parts qualification (i.e., batteries, gyros, RF components, IC's)	DT-III
3. Contractor Demonstration Tests (CDTs) - ALGMs (for specification complicance)	3. a. Environmental and safety qualification (DPT/QT).	DT-IIIB
	b. Reliability demonstration [Lab (simulated operational captive flight)].	
	c. Maintainability demonstration.	
	d. First article configuration inspection.	
4. TECHEVAL	4. a. Performance tests (flight line, captive flight, launch and free flight).	DT-IIIB
	b. Reliability tests (flight line, captive flight, launch and free flight).	
	c. Supportability evaluation (maintainability and logistics related to a/b).	

Figure 4. DT&E Tests.

TEST CATEGORY	TEST SUB-CATEGORY	PHASES
1. IOT&E	1. a. Development assist-support DA for planning and tests during validation phase.	OT-I, OT-II.
	b. Operational assist-project assignment for assessment of program worth prior to full-scale development decision.	OT-II
	c. Test monitoring and assistance-project assignment to limited active participation and test review and monitoring including TECHEVAL surveillance.	OT-III
2. OPEVAL	2. OPERATIONAL EFFECTIVENESS	OT-III
	a. Performance tests (flight line, captive flight, launch and free flight).	
	b. Reliability tests (flight line, captive flight, launch and free flight).	
	OPERATIONAL SUITABILITY	
	c. Maintainability, supportability, compatibility, operability, human factors, training adequacy, tech. pubs.	
3. FOT&E	3. a. Evaluation of fixes incorporated in ALGMs.	OT-IV
	b. Fleet introduction - "lead the fleet program".	
	c. Special reliability tests for early field assessment.	

Figure 5. OT&E Tests.

OT&E is planned by, conducted by or for, and reported directly to CNO by COMOPTEVFOR. With only a relatively modest number of personnel and resources, COMOPTEVFOR relies heavily on the facilities, resources, and personnel of the operating forces and government field activities for carrying out his mission. He exercises operational control over fleet units assigned for project support. Close liaison is authorized and exercised with appropriate elements of NAVMAT, the System Commands (NAVAIR for ALGM) and other T&E organizations to facilitate test support and information flow in carrying out assigned projects [Ref. 5].

E. CONDUCT OF TESTS FOR ALGMs

For DT&E of ALGMs, tests are conducted by contractors, Navy Laboratories, and participating field activities. OPTEVFOR is responsible for the conduct of the OT&E tests, which begin during the validation phase for most ALGM programs. Of importance to note is the planned overlap and concurrence of DT&E and OT&E throughout the acquisition period.

The development contractors perform much of the DT&E testing. Several contractors are involved during the conceptual phase when the various concepts are evaluated. During the validation phase, the selected contractors conduct ground tests, and usually with government aid, conduct captive flight tests and flight test firings. During full-scale development, an ALGM development contractor conducts the DT&E he is contractually responsible for, which includes performance, environmental, reliability tests (as identified in section III C) at the sub-system and system level, on the ground and in captive flight tests and firings. Various contractors responsible for sub-systems of the missile system will perform similar applicable DT&E.

Navy development laboratories and other participating field activities perform DT&E testing in ALGM programs as well. Development laboratories support NAVAIR and the Program Manager in the early conceptual phase and usually continue in this capacity throughout the development cycle. During DT-I the laboratories conduct conceptual evaluations along with the contractors. During DT-II, they work with the selected contractors to demonstrate that design risks have been identified and the DT&E efforts support the Milestone II decision. Laboratories play an especially important role in the conduct of captive and free-flight tests. During DT-III they monitor much of the contractor testing and continue their role in captive and free-flight testing. They provide an assessment of the system and provide DT&E results to the Program Manager for his use concerning the production decision. Participating field activities perform DT&E for the Program Manager in certain subsystem areas which require special skills and/or facilities, namely in warhead, fuze and propulsion areas. PMTC, Point Mugu has historically conducted the TECHEVAL for ALGMs.

OPTEVFOR begins conducting tests and performing evaluations of the ALGM data available during the validation phase's activities. This initial testing in OT-II is in conjunction with the DT&E program, conducting some of the captive flight tests and firings and monitoring the contractor, laboratory and participating field activity testing. This provides the necessary information for OPTEVFOR to make its projected operational effectiveness and suitability assessment for Milestone II. During full-scale development, OPTEVFOR continues to monitor the DT&E efforts and conducts many of the program's captive flights and missile firings. The OT&E efforts in this phase culminates in a formal OPEVAL which OPTEVFOR performs on the system forming the basis for its

Milestone III recommendation. OPTEVFOR also conducts or coordinates the operational testing associated with FOT&E.

F. FACILITIES FOR T&E OF NAVY ALGMs

Navy ALGM programs use six of the 26 activities designated elements of the DoD T&E Facility Base, also referred to as the Major Range and Test Facility (MRTFB). The six are listed below. Associated mission statements as obtained from the Navy RDT&E Management Guide [Ref. 5] are given in Appendix C.

1. Naval Ordnance Missile Test Facility, White Sands, New Mexico
2. Naval Air Test Center, Patuxent River, Maryland
3. Pacific Missile Test Center, Point Mugu, California
4. Naval Weapons Center Ranges, China Lake, California
5. Naval Weapons Laboratory Ranges, Dahlgren, Virginia
6. Naval Explosive Ordnance Disposal Facility, Indian Head, Maryland

The Program Manager and persons responsible for implementation of ALGM T&E projects can obtain the capabilities of these applicable T&E facilities by consulting references cited in Chapter 7, Section 073 of Ref. 1. The key factor in obtaining use of test ranges and other facilities is early contact with cognizant test facilities personnel. Early liaison will assist in the definition of a practical test plan to be incorporated in the TEMP, and will allow the facility the lead time required to provide the required support.

G. FUNDING

T&E funding responsibility rests with the Program Manager. The Program Manager must plan, program, budget, and fund the cost of all resources identified in the approved TEMP for all T&E from initial development through production, except for some fleet related expenses.

This includes all DT&E costs and practically all OT&E costs (OPNAVINST 3960.10 cites the minor exceptions). Since the Program Manager must budget for the OT&E costs, it is essential that COMOPTEVFOR identify all requirements in sufficient time to integrate these into the program schedule and budget cycle [Ref. 4].

H. PLANNING

OPNAVINST 3960.10 implements the planning policy of DoDD 5000.3 by specifying various requirements with regards to the TEMP. It notes that the TEMP defines the test and evaluation efforts for each acquisition program and, as such, contains the integrated requirements of the developing agency for DT&E and COMOPTEVFOR for OT&E, their schedules and resource requirements. It further states that the TEMP will be prepared early in each new acquisition program, and approved prior to Milestone I; the TEMP will be prepared by the development agency with the OT&E portion prepared by COMOPTEVFOR; and that the development agency ensures the TEMP accurately reflects its planned approach to provide the necessary T&E to solve development design issues. Approval of the TEMP constitutes CNO direction to conduct the T&E program defined therein. An enclosure to OPNAVINST 3960.10 provides specific instructions for TEMP preparation [Ref. 4].

In addition to the requirements of the TEMP, Navy T&E planning information is contained in the Decision Coordinating Paper, which is prepared early in the system acquisition process. The Decision Coordinating Paper identifies the critical questions and areas of risk to be resolved by T&E, establishes the initial goals and thresholds, and also includes a summary statement of test objectives, schedules, and milestones. These are updated at subsequent revisions of the Decision

Coordinating Paper, and at the major milestone decision points [Ref. 6].

The Program Manager must plan his T&E efforts early because it constitutes a significant portion of his program budget. A representative budget must be submitted at Milestone I, therefore important and detailed program and T&E planning must occur during the conceptual phase. Plans summarized in the T&E section of the DCP lay the groundwork for earliest possible commencement of T&E and can influence significantly the program's budget. These planning inputs generally are prepared some time before the TEMP is assembled for Milestone I. TEMPs to date contain a level of detail and commitment which has caused them to be somewhat controversial and as a result agreement and approval do not occur until well into the development program.

The budget process contains the impetus to accomplish early T&E planning. In addition, the Program Manager must realize that this early planning enables him to determine the scope, asset and resource requirements of his T&E program. The early visibility will provide the Program Manager with valuable management insight into his planned T&E effort.

I. NAVY T&E PROGRAM REVIEWS

Aside from the program reviews cited in section II-E which are dependent on T&E results for basic inputs, program reviews of T&E are conducted periodically by the Program Manager, his T&E coordinator, or designee for T&E. These reviews, among other things, determine test program status, identify problems and determine corrective action status and responsibilities. Many times the T&E program reviews are a part of the system design reviews, as a broad spectrum of program personnel are

interested in the program's T&E activities. These reviews involve the participation of all T&E agencies responsible for ALGM T&E activities, including contractors, Navy laboratories, participating field activities and OPTEVFOR. However, OPTEVFOR's role in program reviews at the development level is limited, in keeping with its position as the independent test agency. T&E reviews help the T&E activities maintain the impetus and pace commensurate with the ALGM development progress.

J. INFORMATION FLOW AND REVIEW

T&E provides the information for decision-making. Whether it is design evaluation data, operational utilization data, or risk assessment data, the T&E information must be disseminated to users to be useful. The Program Manager is aware of all T&E activity. All DT&E is authorized by the Program Manager and reported to his office. The only exception to this is when development contractors perform design tests as part of their internal development efforts; however, when the Navy requests such data, the contractor is usually cooperative in providing it. Although COMOPTEVFOR reports directly to CNO, COMOPTEVFOR provides significant OT&E test data and analysis to the Program Manager. Thus, through the program office the T&E information is available or provided directly to the necessary users.

The TEMP has been a key document to help in the dissemination of T&E information. Its coordinated and integrated characteristic provides program personnel with visibility as to when tests are occurring, who is responsible, and provides other related test management information. This enables the T&E participants and users of the data to be involved in the testing, either actively or in a monitoring capacity, and to be aware of the availability of T&E information.

The Navy's philosophy of attempting to bring OPTEVFOR into the program's T&E efforts during DT&E helps greatly in an early assessment of the system and planning for OPEVAL. The results from DT&E and OT&E figure prominently in the development of the publications, manuals and training aids for the operating forces. This also pertains to the logisticians in their development and proofing of the Integrated Logistic Support Program.

IV. PROBLEMS IN THE MANAGEMENT OF T&E AND OF CONCERN TO ALGM PROGRAMS

Problems will be addressed which have been identified throughout the T&E community and in ALGM programs, and of which the ALGM Program Manager should be aware. Some of the problems identified are of such a nature that their application can be to many program types or to T&E in general; however, all the problems alluded to should be a specific concern to an ALGM Program Manager, his designee for T&E, or any other individual responsible for implementation of ALGM T&E.

The problems are categorized into five areas:

A. Planning

B. Proliferation of Requirements and Reviews

C. Resource and Schedule Constraints

D. Redundant Testing

E. Management of Diverse Activities and Functions

A. PLANNING

Probably the foremost problem relative to inadequate and inefficient T&E is poor planning by those responsible for performance and implementation of the program. Planning problems encompass several dimensions, some of the important ones being:

1. Inadequate and uncoordinated planning early in the development cycle and among the various responsible organizations

2. Implementation of "success oriented" planning

3. Lack of flexibility in T&E planning to accommodate problems and unknowns

4. Unrealistic requirements in the planning efforts

5. Lack of design of tests, definition of test criteria, and knowing the use of the test data

6. Lack of definition of a mission profile

7. Difficulty in converting operational requirements into test specification requirements

8. Inability to convert specification performance requirements into T&E asset (resource) requirements

These problems are discussed in the following sections.

1. Inadequate and uncoordinated planning efforts early in the development cycle and among the various responsible organizations

Inadequate T&E planning has been the source of many difficulties, and has resulted in some cost and schedule growth in development programs. Planning simply was not being performed early enough in the development cycle, and when it was performed, many times it was incomplete, covering primarily DT&E. This demonstrated the lack of the user's input. As a result initial program budget submittals at Milestone I were very deficient in the T&E area.

The requirement for a TEMP to exist at the major milestones (including Milestone I) for each program is an attempt to correct this problem. Unfortunately, many TEMPs do not exist until Milestone II, thus allowing the opportunity for many differences between what is presented at Milestone I and Milestone II. In discussions with OPNAV 983, it was brought out that only a small percentage of program TEMPs are approved by Milestone II (a number as low as 10%). This may be because the requirement for a TEMP is relatively new (since 1975); however, it may also be an example of people dragging their feet on implementing directives. There appears to be no sanction of the document and no

penalty against programs which do not have a TEMP. Also, NAVAIR has yet to flow down implementation and guideline instructions to the upper level directives.

Many times the T&E program plans submitted were not coordinated between the various T&E organizations and responsible program people. This situation may exist when a program does not have a T&E coordinator or the Program Manager allows disjointed efforts to exist. Adequate early planning would minimize this situation. Again, the requirement for a TEMP is an attempt to obtain a coordinated T&E program. A coordinated program can also help to reduce another major problem, redundant testing.

The Defense Science Board, in the reports of its task force on T&E, reported an indication of widespread inadequate early planning for T&E in past programs [Refs. 14 and 15].

2. Implementation of "success-oriented" planning

When test planning is performed, it generally includes all known testing requirements and contains some integration of the testing activities. However, the planning is basically "success-oriented", whereby test failures with corresponding contingencies are not included in the plans. Only in flight testing are back-up tests consistently identified, although many times insufficient. Ground testing, especially in DT&E, suffers from this characteristic. The Defense Science Board in its most recent review on T&E also stated that success-oriented planning was performed [Ref. 15].

3. Lack of flexibility in T&E planning to accommodate problems and unknowns

Many times the test program planned did not allow sufficiently for problem solving and unknown situations which surface during

development, contributing to schedule stretchout and increased cost in test programs. This is a very difficult feature to plan for, but one to which the Program Manager should give more attention in future planning. Many times problems are uncovered during testing, or some unknown occurs, which necessitate changes in the course of action. However, a real difficulty exists in that many times program funds and schedules do not possess the flexibility required to make the necessary program adjustments. This situation was highlighted by the Defense Science Board [Refs. 14 and 15]. In discussions they had with industry representatives, industry indicated almost universally an erosion process of program contingency funds throughout the bidding and negotiation process.

4. Unrealistic requirements in the planning effort

Since the implementation of DoDD 5000.3 in 1973, improved planning has taken place in T&E. The OT&E people of COMOPTEVFOR were given a strengthened charter which they have proceeded to implement. However, the organizations responsible for DT&E have existing "standard operating procedures" which they implement. Combining these two perceptions into the test program plans resulted in an abundance of testing being specified, with high cost T&E programs. During this period, studies were reporting that inadequate and insufficient T&E was being performed. Future planning must look for most cost-effective T&E programs.

5. Lack of design of tests, definition of test criteria, and knowing the use of the test data

Poor planning in the design of tests, definition of test criteria, and in not knowing the expected use of the test data results in proliferation of testing, as well as wasteful testing and testing with questionable results. Such a situation should not exist in today's

limited funding environment. Testing, especially flight testing, is very expensive. This problem includes both DT&E and OT&E. The OT&E people must be especially concerned with this situation because of their desire to test in the operational environment which is more difficult and costly.

The Defense Science Board report contains several guidelines relative to design of tests which are appropriate to consider. They include:

a. "Ensure that the whole system, including the user people, is tested. Realistically test the complete system, including hardware, software, people and interfaces.

b. Ascertain that sufficient time and test articles are planned. When the technology is stressed, the higher risks require more test articles and time.

c. In general, parts, sub-systems and systems should be proven in that order before incorporating them into the next higher assembly for more complete tests.

d. Major tests should never be repeated without an analysis of failures and corrective action" [Ref. 7].

6. Lack of definition of a mission profile

In recent years, the value of a mission profile or the several mission profiles of a weapon system has been realized and become a requirement for programs. This resulted from a weakness in the user-producer dialogue. The operational requirements of the user were not getting into the development specifications. The DSB refers to this recommending that specification requirements be stated in functional terms rather than design values, necessitating strong user involvement [Ref. 14].

Specifying a system's mission profile requires knowledge of the operational performance requirements, and incorporates a realism into requirements and subsequent testing. Obtaining a system's mission

profile requires planned and coordinated efforts by the program's using, development, and testing teams. The lack of this in the past has contributed to wasteful, inefficient and less than desirable T&E efforts.

7. Difficulty in converting operational requirements into test specification requirements

This has been a problem for many years and probably will continue to be a prime area for improvement in the future. Better early planning can minimize this difficulty, along with an improved user-producer dialogue. During the generation of the system's performance and design specifications, operational requirements should be the source for these specifications, with strong user involvement. At the same time, the user-producer dialogue must be extended to include test program planning with the specification generation task. Only if this is done will the DT&E and OT&E programs be testing real operational or operational related requirements. The Defense Science Board in its most recent study cited inadequate requirements statements as a problem [Ref. 15].

Currently OPTEVFOR is closest to the operational community; however, in many instances its personnel lack expertise to translate the perceived operational requirements into development specification language. Also, OPNAV, which is a user organization, appears to be often influenced by technical inputs from contractors and development laboratories. Thus, the operational requirements may be losing user representation.

8. Inability to convert specification performance requirements into T&E asset (resource) requirements

When the test agencies have made their inputs, and the test performance requirements have been established, the problem exists of converting these into resource requirements. It is important to perform a requirements analysis in conjunction with the design of the test to

determine the asset limitations, both from feasibility and affordability points of view. The testing required to perform the desired program is simply resource limited. Among resource considerations are such items as facilities, personnel, test hardware, threat simulation, and support equipment. Both the NMARC study [Ref. 16] and Defense Science Board report [Ref. 14] identified this limitation in Navy T&E. Test resources are not keeping pace with development program requirements.

In general, the Navy must continue to make improvements in its T&E planning. With progress being made through the implementation of DoDD 5000.3 and OPNAVINST 3960.10, and the subsequent TEMP, plans for T&E should be improved. However, this result is not yet clearly apparent. Much work is being expended, supported by the fact that many TEMPs are in progress or draft form, but only a small percentage are formally approved. Additional efforts to perform planning earlier in the development phases would prove to be beneficial. In addition to providing the Program Manager with valuable management information, such early planning could be used as a "strawman" for the TEMP, thus possibly reducing its generation and approval cycle time. This early planning would also highlight any potential T&E gaps which impact on program milestone decisions (T&E gaps are breaks in testing due to hardware unavailability, anywhere during the development and production cycle, not just between IOT&E and FOT&E as used in Ref. 14). This early planning must also involve very strongly the user and OPTEVFOR.

B. PROLIFERATION OF REQUIREMENTS AND REVIEWS

During the performance of T&E throughout the development cycle, new requirements surface and are imposed on existing programs as well as new ones. These requirements are not planned for because they did not

exist at the time of planning. Such requirements might be in the form of AR's (Aeronautical Requirements) which are essentially new requirements which generally affect testing procedures. Other requirements might be program reviews which were not anticipated and may reflect a current fleet concern or a shift in emphasis in certain disciplines (e.g., reliability). Examples of such reviews at the Washington level were the developing agency special management reviews addressing heavily the reliability concern, and the production reliability design review [Refs. 17 and 18]. Progress on the development program and in T&E is affected by such reviews because of the support required to prepare and perform the reviews. Reviews such as these are not provided for in program budgets and contribute to a depletion of the management discretionary funds. Review requirements such as these also seem to come and go, depending on the people in the review chair or those in power. The NMARC report cited the difficulty the Program Manager has responding to all reviewers and requirements from the many layers of people in the Navy organization [Ref. 16].

There are other reviews which impact on T&E as well. Reviews at participating field activities such as design reviews, environmental and qualification program reviews, and those related to range safety require special efforts from the T&E organization and many times are beyond that planned in the budget. Proper attention to such requirements in early planning could minimize this impact. However, a proliferation of these requirements may be detrimental to efficient development progress.

Unique capabilities may fall into the category of proliferation. For example, some test activities may have built up capabilities over the years, both in facilities and manpower, which are quite special,

and these activities tend to perpetuate the use of such capabilities and their existence. Capabilities such as PMTC, Point Mugu's acoustic vibration facility and Naval Explosive Ordnance Disposal Facility (NEODF) Indian Head's propellant manufacturing and testing capability fall into this category. Although these facilities and capabilities are important ones, they may not fit into every program's T&E plans. However, once activities possess a unique capability, the activities are determined to keep it in use. Thus, requirements may be imposed on the program to include the use of these special test facilities as part of the test program. The more logical approach is for the program to determine what testing is required and then determine the best method and place to accomplish that testing.

C. RESOURCE AND SCHEDULE CONSTRAINTS

Resource and schedule constraints add to the complexity of accomplishing the T&E assignment. These constraints have been used as an excuse for non-compliance with directives and instructions applicable to defense development programs [Ref. 14].

The primary resources for T&E are personnel, facilities and equipment. Talented T&E people are key to performing the T&E function. T&E suffers from a lack of talented people and this area must be made more attractive and rewarding. Facilities, ranges, instrumentation and support equipment are growing obsolete and have maintenance problems. With the decrease of defense funding in the 1970's, less flight testing is performed and fewer dollars are available to maintain ranges and facilities at acceptable levels. In addition, there is a need to incorporate improvements necessary to keep pace with the newer, more sophisticated missile systems currently being developed. Support equipment is often overlooked

in the choice for new targets, range upgrading or repair, but equipment such as range trackers and telemetry systems are equally important in achieving satisfactory T&E. The NMARC report, the Defense Science Board reports and discussions with the NWC, China Lake T&E facility manager all highlighted this problem relating to T&E resources [Refs. 14, 15, and 16].

A recent concern related to maintaining adequate test ranges has been encroachment by civil activities on the government's vast range land and the sea and airspace needed for testing. Such a movement is a potential threat to this test resource. Lt Gen W. E. Lotz (Ret), head of DD(T&E), cited this problem as very real in his presentation to Congress on defense T&E [Ref. 3].

Schedule constraints may be the single greatest excuse given for not accomplishing the T&E plans or why T&E is performed out of sequence with program milestones. Usually programs are striving to meet or better a schedule, but many times there is some program slippage. When program decision points are based on a predetermined schedule, many times the decision milestone takes place and the following phase is initiated before the T&E is completed, because T&E characteristically is more prevalent in the latter part of the development phase. The report of the Commission on Government Procurement cited the existence of this situation and recommended instead that milestone decisions be based on program information and T&E results [Ref. 11]. The Defense Science Board also noted this situation and made a similar comment [Ref. 15]. However, schedule constraints continue to prevail because people in command are uncomfortable with flexible milestones and the budget cycle operates from a fixed schedule base.

DD(T&E) does make a major recommendation to DDR&E at the program milestone reviews. However, rarely has a program been stopped because of insufficient T&E. This occurs because there are very few yes and no answers in T&E, creating a wide zone of uncertainty, risk and judgement evaluation. But, as the Defense Science Board reported, DD(T&E) and the milestone decision makers have been unable to make risk assessments, and the program has moved on according to the calendar driven schedule [Ref. 15]. Management must better address this situation, develop new plans and procedures, and then adhere to performance driven milestones. The latest directives relative to system acquisition, currently in review, are attempting to mandate performance driven milestones rather than schedule driven milestones.

D. REDUNDANT TESTING

Redundant testing is testing more than is necessary through duplicative efforts among various test agencies. The potential for increased redundant testing has occurred since the issuance of the new directives in the 1970s with their added emphasis on test and evaluation. These new directives, as applied to the Navy, gave OPTEVFOR additional responsibility and stature, resulting in an expansion of OT&E testing requirements. The requirements of DT&E have remained the same with some inherent redundant testing built into the development program as the government provided a "watchdog" function on the contractor. The combined effect of the OT&E and DT&E requirements results in additional duplication of tests. Prime examples of this situation in ALGM programs are in environmental testing, reliability testing, and captive flight testing.

In environmental testing the development contractor is required by his contract to perform environmental tests on the system and applicable sub-systems. The Navy then proceeds to repeat much of the testing during its TECHEVAL at PMTC, Point Mugu. This is classified as confirmation of the contractor's tests. In the past, much of this type of testing was performed to prepare or train Point Mugu for its role in fleet related testing after IOC. Such redundant testing simply depletes the already strained RDT&E budget.

The situation in reliability testing could become quite serious. There has been much emphasis on reliability in the past several years because of high maintenance costs and fleet disappointment in weapon systems that did not perform at all or to their advertised capability. As a result, many T&E organizations are proposing their own reliability test and demonstration program for the same weapon system. Also, many people in program review positions are encouraging and/or requiring the demonstration test programs. However, the fact must not be overlooked that such testing is quite expensive and a large amount of testing is required for any one organization to be able to state a reliability from a demonstration program with any high level of confidence. For example, if a missile has a reliability requirement of 75 hrs MTBF, 700 hrs of operating time with no more than 5 failures are required to demonstrate at the 90% confidence level the specified reliability requirement (based on the exponential distribution assumption). The contractor is contractually required to demonstrate the reliability of the system. That alone requires a substantial amount of testing. A requirement for TECHEVAL people and the OT&E people also to perform reliability demonstration test programs is often uneconomical and redundant. Each

organization would claim, though, that its demonstration program was different because of environmental changes.

In captive flight testing of ALGMs, tests are performed by the development agency (contractor and Navy development laboratory) as part of DT&E, the TECHEVAL agency, also as part of DT&E, and OPTEVFOR as part of OT&E. Although some unique tests are performed by each test agency, there is some duplication as well. Claims of program advocacy by the development agency and testing by "independent" test agencies are reasons used to justify such redundant testing.

The question of redundant testing must be examined carefully before implementation because of the tight fiscal situation of present times. It appears reasonable that through proper planning of the development contractor's test program and associated monitoring by the Navy, some redundant testing could be eliminated. In addressing the problem of redundant testing, the objective should not be to remove all duplication. It should ensure that where such duplication exists, it is visible, affordable, controlled, purposeful, and contributes appropriately to the T&E program. The Defense Science Board noted that there appeared to be little or no overtesting done under the current directives, but some redundant testing occurred [Ref. 15].

E. MANAGEMENT OF DIVERSE ACTIVITIES AND FUNCTIONS

One of the significant difficulties which is often overlooked in managing T&E is that the Program Manager and T&E coordinator must deal with many diverse activities and functions. In addition to DD(T&E) in OSD, OPTEVFOR and OP-983 in OPNAV, the T&E manager must operate with the matrix organizational structure of the Navy for his functional T&E and technical support. Many of the T&E activities and organizations

within the Navy possess their own standard operating procedures and exhibit various forms of parochialism. Dealing with this characteristic requires special talents and capabilities by the T&E manager in order to operate effectively. The important point is to realize everyone's position when the T&E planning takes place.

Management of the Navy and development contractor activities simultaneously, their interfaces and interfacing, is another formidable task for the ALGM Program Manager. Many times competition and adversary relationships exist between the two groups. In T&E it is often the Navy's position that the contractor has something to gain by taking advantage of the Navy and will do so in its testing program. There is disagreement between the two organizations performing the tests partly because the contractor feels it's his responsibility and the Navy feels it must perform the tests to validate the results. Much of the current thinking in ALGM programs is that the system development contractor is responsible for all the development activities, including the many aspects of T&E from component and assembly testing to system flight testing. This creates a management problem in that the Navy is responsible for the aircraft and test ranges where the system flight testing is performed.

In summary, it is necessary for the ALGM Program Manager to be conscious of each problem in order for him to better manage and implement a successful and effective T&E effort. Sometimes the problem situation is of such a nature that the ALGM Program Manager has little opportunity to exert influence on or correct the ultimate outcome; however, simply realizing the problem exists helps him tolerate the situation. Nevertheless, many of the T&E management problems can be dealt with directly by the ALGM Program Manager.

The T&E management problems identified in this section will be addressed in the following discussion of potential alternatives for performing an ALGM program's T&E. Some of the problems will be more prevalent in one alternative than in another.

V. AIR-LAUNCHED GUIDED MISSILE T&E PROGRAM MANAGEMENT ALTERNATIVE APPROACHES

The Program Manager has several basic approaches or alternatives with respect to implementation of an "adequate" T&E Program for an ALGM. Four alternatives will be considered in this section, all of which are basically compatible with the requirements and guidelines of DoDD 5000.3 and OPNAVINST 3960.10. The four alternatives are:

A. Separate Test Programs in Series

B. Combined Test Programs

C. Integrated Test Programs

D. System Level Functional Test Program

Each alternative when analyzed suffers to a certain extent from the T&E management problems identified in section IV. The applicability of those management problems and other problems to a particular alternative is discussed in this section. The good features of each approach are also discussed.

A. SEPARATE TEST PROGRAMS IN SERIES

1. Management Approach

The Separate Test Programs in Series management approach adheres rigidly to the requirements and guidelines of OPNAVINST 3960.10 and is a means of implementing DT&E and OT&E efforts similar to those described in section IIIc. The Program Manager attempts to structure the T&E program utilizing contractors, participating field activities, and support activities. Each program T&E participant will advocate and attempt to conduct its own test program to demonstrate ALGM specification

and or DCP compliance. The nature and degree of independence of each participant will be reflected in the structured inputs to the TEMP preparation and review cycle resulting in basically three separate test programs being conducted as follows:

a. Contractor Program

DT-I through DT-III as described in section III C 1 culminating with Contractor Demonstration Tests, including:

(1) Part and component qualification, assembly, and sub-system tests (accelerated life, overstress, and design evaluation and qualification), sub-system and section integration and compatibility tests.

(2) ALGM system level performance tests both on the ground (chamber tests), on board the aircraft, and in the captive carry mode concluding with several missile launches from aircraft,

(3) reliability demonstration for compatibility with specification requirements (ground and airborne) testing for captive carry MTBF, launch from aircraft and free flight to target reliability) at the required confidence levels,

(4) maintainability demonstration for compatibility with specification requirements,

(5) environmental and safety qualification (including electromagnetic compatibility) to verify compliance with specification design requirements.

b. TECHEVAL Program

Performed during the final sub-phase of DT-III and includes:

(1) ALGM system level performance both on the ground (chamber tests), on board the aircraft, and in the captive carry mode concluding with several missile launches from aircraft,

(2) reliability demonstration for compatibility with specification requirements (ground and airborne testing for captive carry MTBF, launch and free flight to target reliability) at the specification required confidence levels,

(3) maintainability evaluation,

(4) environmental tests to verify compliance with specification design requirements.

Occasionally, the TECHEVAL environmental tests have included overstress tests to evaluate hardware design margins.

c. OT&E Program

OT-II and OT-III as described in section III C 2 culminating with OPEVAL, which includes:

(1) ALGM system level performance tests on board the aircraft, on the ground and in the captive carry mode concluding with several missile launches from the aircraft,

(2) airborne evaluation of captive carry MTBF and free flight to target reliability for compliance with the ALGM system specification confidence levels,

(3) evaluation of ALGM system maintainability characteristics.

Other operational suitability characteristics of the ALGM evaluated are: compatibility, interoperability including human factors, and

logistic and training adequacy. Additionally, OPTEVFOR will continue tactics development and refinement.

d. FOT&E Program

OT-IV, as described in section III C 3, may be conducted by OPTEVFOR but is rarely defined and/or planned for early in the program's life. FOT&E is beyond the scope of this thesis.

2. Applicable T&E Management Problems

The principal Developing Agency for Navy ALGM's is the Naval Air Systems Command and AIR-06 is its responsible T&E agency (Figure 6). AIR-06 has been in existence for approximately three years and has not as yet promulgated T&E Instructions or Guidelines in response to OPNAVINST 3960.10. This has contributed to something less than full implementation of DoDD 5000.3 and OPNAVINST 3960.10 T&E requirements and permits circumstances such as the Separate Test Programs in series to occur too easily rather than explore a more efficient process. According to AIR-06 personnel, it has been very difficult for AIR-06 to effectively impact ALGM T&E programs and to fully and efficiently implement the TEMP process because of the lack of published T&E instructions. A further constraint to date on AIR-06's effectiveness is the fact that its personnel have been utilized for the most part only in an advisory capacity by ALGM Program Managers. Thus, without more specific guidance and direction from within NAVAIR, TEMP preparation has been dragging and ALGM T&E management problems similar to those described in section IV continue. T&E management problems arising from the Separate Test Programs in Series method of operation are as follows:

a. Planning

As previously indicated in section IVA.1, NAVAIR's current position with respect to flowdown of T&E implementation and guideline

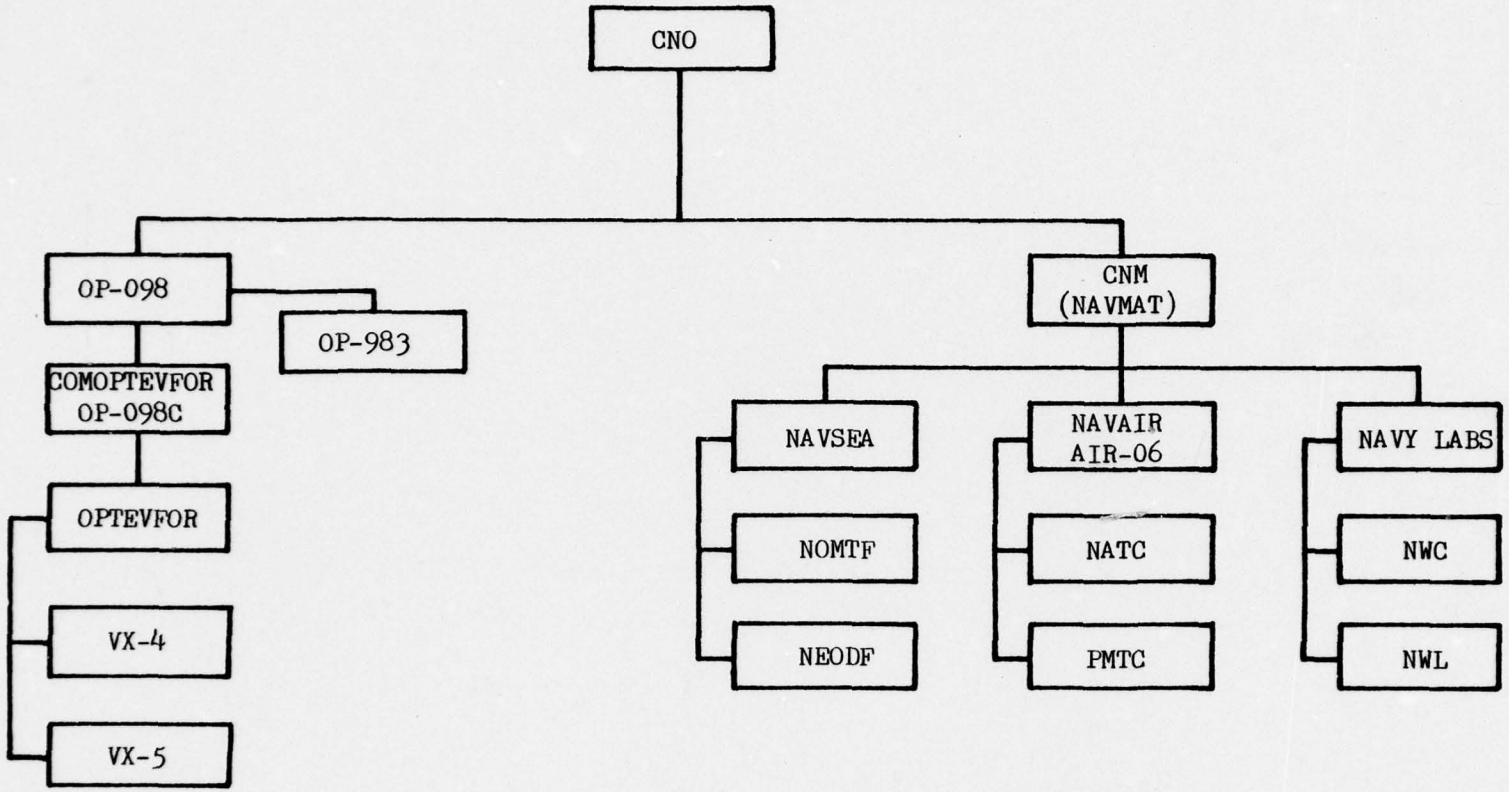

Figure 6. Navy Responsible ALGM T&E Agencies

instructions, makes it difficult to influence or even impress upon ALGM Program Managers the necessity for early, thorough T&E planning. Further complicating this situation, is the fact that DD(T&E), OP-983C, and NAVMAT have all indicated, when interviewed by the authors, that a strawman TEMP is all that is required and reasonable to expect for Milestone I. It was stated also that OPTEVFOR was usually not available for early planning efforts prior to the Milestone I TEMP effort because of its heavy involvement in OPEVALs. A contradiction exists in that OPTEVFOR personnel, when interviewed, indicated problems with early planning prior to Milestone I were due to reluctance on the part of Program Managers to commit to supporting a detailed T&E program. OPTEVFOR further stated that there were no real sanctions imposed on the Program Managers or their programs if they did not do the necessary thorough investigation and planning effort. Too often, Program Managers are unable or unwilling, because of the myriad of tasks in the early stages of the program, to come to grips with the T&E details and to challenge or even question established precedents or standard operating procedures. Under these circumstances, T&E programs like the Separate Test Programs in series can result. Once brought to life at Milestone I, the drain on scarce program resources commences and is extremely difficult to curb and control.

b. Proliferation of Requirements

With the Separate Test Programs in series approach the Program Manager is much more likely to be confronted with proliferating requirements which impinge on scarce program resources. ACAT I or II programs usually have many diverse participants (participating field activities, such as : PMTC, NWC, NWL) who have unique internal requirements which must be satisfied during the life of the program. These requirements may take the form of management review, special technical

reviews, special test programs or regimes, and additional requirements designed to perpetuate utilization of unique facilities or capabilities. For example, NWC, which has functioned as Technical Manager for NAVAIR on several ALGM programs and as a participating field activity developing major components on other ALGM programs, has internal instructions which require extensive management reviews (e.g., Design Review Committee, Environmental Qualification Review Panel, Ammunition Safety Committee). Any or all of these retain the authority to impose requirements for additional program resources, i.e., additional ALGM assets for testing (larger quantities), additional tests or sequences which may require different or enhanced facilities or more schedule time.

TECHEVAL's conducted at PMTC invariably "require" subjection of ALGM's to extensive environmental tests not only to verify compliance with specification design requirements but also to evaluate design margins (i.e., overstress or test to failure type of tests). PMTC also is a proponent of acoustic vibration chamber testing and possesses one of the few facilities of this type capable of testing all-up-round ALGM's. Consequently, ALGM ground reliability tests (simulating the captive flight environment) are conducted to demonstrate the specified MTBF at the required confidence level using this chamber. This is required even though the ALGM contractor has already performed a similar demonstration to satisfy contractual provisions under a government approved procedure with government monitoring.

The Program Managers are often faced with high level management review similar to those reported by NMARC [Ref. 16]. The reviews utilize T&E data and are usually conducted at such a high level (Flag Rank) that the program essentially comes to a halt while presentations

are prepared, participants assemble, and the review occurs. Quite commonly, this occurs several times during ALGM development and impacts significantly on program resources.

With the increased emphasis on IOT&E, OPTEVFOR is involved in monitoring DT&E activities. In addition to operational testing, OPTEVFOR personnel have said in recent interviews that they may choose to repeat DT&E testing where apparent weaknesses were revealed.

c. Resource and Schedule Constraints

The Separate Test Programs in Series approach can present especially significant resource and schedule constraint problems for the Program Manager or his designee for T&E. Inadequate early coordinated planning impacts severely on lead times necessary to acquire requisite facilities and instrumentation with appropriate staffs which may be necessary to support new ALGM technology. A further problem aggravating this situation is the fact that the Navy's Test and Evaluation Facility base is still loosely knit and without strong central coordination. NMARC [Ref. 16] commented on this problem and made several recommendations which should improve the situation as NAVAIRs relatively new T&E Directorate, (AIR-06), assumes its leadership role.

With the high possibility for duplicative testing under the Separate Test Programs in Series approach, problems like facility scheduling and allocation of priorities, become quite significant. OPTEVFOR possesses no facilities, instrumentation, or ranges of its own and, because of the nature of some ALGM's, must rely on DT&E resources to conduct tests for it. Certain range and instrumentation capabilities available only at government facilities are required throughout the ALGM development cycle and present a constant scheduling problem because of contractor, Navy lab, and OPTEVFOR requirements.

Another aspect of the resource and schedule constraints related to facilities, instrumentation, and ranges is the impact of obsolescence and increased maintenance costs. The Navy's facilities are having a difficult time keeping pace with technological advances in weaponry and expanded emphasis on testing is requiring more maintenance on existing facilities and instrumentation. This was confirmed in a recent interview with the Head of the NWC T&E organization, where many ALGM tests are conducted.

d. Redundant Testing

Contractor contractually required Reliability Demonstration (both ground and airborne) and Environmental Qualficiation tests are repeated during ALGM TECHEVAL. OPTEVFOR conducts what amounts to an airborne Reliability Demonstration [Ref. 19] during its evaluation of ALGM operational effectiveness and suitability. The redundancy problem occurs because the agencies cited feel that must repeat or independently conduct reliability test programs to verify compliance with specification minimum acceptable MTBFs or probabilities of success at the stated confidence levels even though the contractor may have successfully done so. This can require an extraordinary amount of time (schedule), a significant commitment of aircraft and manpower, and a very large number of ALGM test assets.

e. Management of Diverse Activities and Functions

The Separate Test Programs in Series approach severely taxes the matrix management approach which ALGM Program Managers are compelled to use as a matter of policy. In the current environment of the shrinking dollar and fewer new programs, competition between field activities for T&E work is strong and the feeling of the need to perpetuate activities and capabilities is pervasive throughout the

Navy's T&E community. The competition between Navy activities within DoD's Major Range and Test Facility Base (e.g., PMTC, NATC, and NWC) creates borderline adversary relationships that require careful handling on the part of the Program Manager or T&E coordinator to assure successful, timely execution of the T&E program.

Another facet of this competitive situation is that DD(T&E) is actively pursuing reduction of unwarranted duplication of facilities and functions among facilities which constitute the Major Range and Test Facility Base (MRTFB) [Ref. 3].

3. Other Problems

There are several problems outside the five basic areas identified in section IVA.1 which also impact the Program Manager in his attempt at planning and implementing an adequate T&E program using the Separate Test Programs in Series approach. These other problems influence the T&E program as follows:

a. If the Separate Test Programs in Series approach is followed, with little or no interplay between DT&E and OT&E while the program is stretched out, appropriate attention may not be directed toward maintenance of the capability to meet the threat. The ALGM may satisfy the specification requirements but when subjected to more stringent OT&E tests, particularly OPEVAL, may be found inadequate to meet the evolving threat.

b. With this approach (Separate Test Programs in Series), stretchout of the schedule and consequent dollar impact means that there will be a great deal of pressure on OPTEVFOR to expedite OPEVAL because of the rapidly approaching IOC date. There will be entreaties to compromise test objectives to conserve assets and shorten the time

frame and somehow soften the dollar crunch. This same situation will also make it extremely difficult to plan and execute the FOT&E effort.

c. ALGM specifications are still stated in terms of engineering design requirements and performance parameters measurable in the laboratory which may not be relevant to an operational commander, according to OPTEVFOR representatives. Without specifications stated in operational terms, it is difficult for OPTEVFOR to translate specification requirements into operational requirements and evaluate test results accordingly. The Commission on Government Procurement [Ref. 11] observed this same problem and suggested that once the engineering specifications are validated in the DT&E effort, the IOT&E effort should be directed toward determining whether they have operational value or not.

d. According to a DD(T&E) staff member when interviewed recently, DD(T&E) places little reliance on DT&E test data, including TECHEVALs, because of the lack of independence from the Developing Agency and because of contractor's and the Program Manager's program advocacies reflected in their interpretation of test data and presentation of results; i.e., need to sell the program. They (DD(T&E)) feel that OPTEVFOR is objective and unbiased and that operational testing is the prime valid measure of an ALGM's worth and utility and this enables them to provide the DSARC with objective unbiased data for the decision making process. DD(T&E) feels however that OPTEVFOR needs more analytical and technical expertise, citing their past difficulty in overall test planning and design of experiment and pointing to a future need for the ability to perform simulations which are going to have to play a larger role in future T&E programs because of escalating ALGM asset costs and test costs.

4. Good Features

Good features of the Separate Test Programs in Series approach are as follows:

a. The competition created between T&E activities within the Navy T&E community, while hard on the personnel involved, may yield a more efficient, technically competent Major Range and Test Facility Base, because it may at least force internal self-examination of capabilities, costs, and personnel, leading to reduction of duplication.

b. DD(T&E) places more emphasis and reliance on operational test results; therefore, with the potential for more data regarding the ALGM's effectiveness and suitability, the DSARC decision process may be easier with less risk. The other potential attribute is that more time is available for proofing and debugging software so that it is possibly less of a problem when initially deployed.

B. COMBINED TESTING

DoDD 5000.3 states that, "development testing and early phases of operational testing may be combined where separation would cause delay involving unacceptable military risk, or would cause an unacceptable increase in the acquisition cost of the system" [Ref. 6].

1. Management Approach

The latter portion of the quote from DoDD 5000.3 would seem to provide some relief to the Program Manager when faced with inputs to the TEMP from the T&E participants which appear similar to those discussed under Separate Test Programs in Series; i.e., separately conducted duplicative and redundant test programs that can cause an unacceptable increase in the ALGM's acquisition cost. If this problem is recognized early enough in the T&E planning stages, a viable management

alternative for the Program Manager is to strive for a Combined Testing approach through the medium of the TEMP preparation and review cycle. This discussion assumes the Program Manager is faced with just such a situation, recognizes it sometime prior to Milestone II and attempts to rectify the projected schedule and cost growth through combining elements of DT&E and OT&E. The proposed elements of the TEMP (i.e., Contractor Test Program, TECHEVAL Program, and OT&E Program) are essentially the same as presented in the preceding section VI A.

OPNAVINST 3960.10 permits combined testing but states that, "the final sub-phases of DT-III and OT-III (TECHEVAL and OPEVAL) will not normally be combined". While this appears to be a significant hindrance, the major obstacle for the Program Manager to overcome is the fact that he and COMOPTEVFOR are jointly responsible for preparation of the TEMP and if they cannot achieve agreement the problem is passed to the OPNAV program sponsor via OP-983. The Program Manager states the areas of disagreement when the TEMP is submitted and COMOPTEVFOR responds, in writing, with the rationale for those areas where there appears to be disagreement. Due to the Navy's command structure, with COMOPTEVFOR being double-hatted and filling the position of DCNO for T&E, the Program Manager would appear to be in a disadvantageous position when taking exception to the OT&E program.

TECHEVAL is an equally difficult area for the Program Manager to modify or waive because of NAVAIR standard operating procedures. With few exceptions, ALGM Program Managers find it almost impossible to modify the approach to ALGM TECHEVAL historically taken by PMTC, Point Mugu, because the NAVAIR T&E community looks upon this as its "independent" evaluation of the system.

The most likely candidates for combining tests appear to be those ALGM system level tests where aircraft are involved such as, system compatibility and integration tests (ALGM, launcher, aircraft, avionics), captive flight performance and reliability tests, missile launch and free flight tests. The aforementioned tests are commonly performed in the DT&E phase by the contractor (though the contractor rarely operates the aircraft) and the TECHEVAL activity, and during OT&E by OPTEVFOR. If tests are combined and replications avoided, T&E cost growth and schedule problems present with the Separate Test Programs in Series should be significantly reduced.

2. Applicable T&E Management Problems

In addition to those problems alluded to in the preceding paragraphs, a number of significant problems remain, primarily in the areas of planning and resource and schedule constraints. Management of diverse activities and functions and proliferation of requirements, as previously discussed, will continue to be a problem but do not require further amplification here. The problem of redundant testing will be ameliorated to some extent by the combined testing approach.

a. Planning

The immediate problem in planning for combined testing stems from the OPNAVINST 3960.10 prohibition on combining TECHEVAL and OPEVAL, since these test programs appear to be quite similar. This prohibition relates to the basic purpose of DT&E and OT&E, i.e., DT&E is designed to assure that the contractual specifications have been met and OT&E determines whether the system fulfills the desired functions in an operational environment. OPTEVFOR also contends its evaluation is objective and unbiased, whereas TECHEVAL is not because PMTC

is part of the Developing Agency (NAVAIR). The Program Manager and other T&E planners must keep in mind that when combined testing is conducted, OPNAVINST 3960.10 requires that the necessary test conditions and test data required by both the DoD component developing agency and the OT&E agency must be realized. This may be difficult to accomplish because DT&E tests are usually structured to hold many parameters constant, isolate others, and allow measurement of specific quantities of interest. COMOPTEVFOR says this is usually not possible in OT&E and it is often not even possible to specify what OPTEVFOR wants to measure. The objective is often to create conditions as close to combat conditions as possible and watch what happens [Ref. 13].

A significant problem to the T&E planners (with DT&E and OT&E combined) will be resolution of the criteria for determining whether tests have been successful or not, i.e., agreement on test objectives and technical measures of effectiveness will be difficult to achieve and whether or not to proceed to the next test or series of tests may be quite controversial. The Commission on Government Procurement [Ref. 11] recognized this situation could exist and addressed the problem of applicability of engineering specifications to the operational environment by recommending some form of early OT&E to make sure that engineering specifications have operational value.

Finally, OPNAVINST 3960.10 requires that the OT&E agency "insure that the combined test is so planned and executed as to provide the necessary operational test information; participate actively in the test; and provide separate evaluation of the resultant operational test information". The planning and execution may be the most difficult aspect to assure. OPTEVFOR indicated that Program Managers seldom involve them early in the program, particularly, in the early planning,

but said the situation is improving. The major problem would appear to be the planning for the execution of the test. OPTEVFOR stresses an uncontrolled operational type of environment with operational personnel, i.e., people not specially trained, not test pilots, not technicians or engineers, but like typical officers and men in the fleet.

b. Resource and Schedule Constraints

T&E resources for combined testing are of special concern. Test facilities and ranges that would be required for ALGM combined testing are primarily R&D oriented. They possess good-to-excellent instrumentation with a high degree of precision in measurement, but have very little flexibility with regard to the environment or method of application, i.e., not flexible in terms of application of operational tactics. The Blue Ribbon Panel noted problems in 1970 [Ref. 8], many of which are still with us today. Most of the facilities and ranges with state-of-the-art capability (i.e., maneuvering room and/or target complexes) are in great demand from a scheduling standpoint just to satisfy development (R&D) requirements.

3. Other Problems

Several facets of the development process and DT&E make a combined DT&E and OT&E evaluation very unlikely. The very nature of the evolution of the ALGM product through DT&E (building block testing from components to systems), limited design disclosure documentation to support it, and the evolutionary philosophy itself (design-test-redesign-retest) are inhibiting factors. Finally, OPTEVFOR finds that test objectives for development hardware tests are usually very limited and contractors and Program Managers are usually unwilling to test development hardware under operational conditions until late in the program.

4. Good Features

The obvious good feature of the combined testing approach is the potential opportunity to conserve the T&E schedule and optimize the utilization of ALGM and test facility assets, thus improving the program's cost posture. Another facet is the requirement for an early positive involvement of the OT&E forces to assure compatibility of the ALGM engineering specifications with the operational environment in which the weapon will have to perform.

Finally, the Defense Science Board observed in its 1977 report [Ref. 15] that a means should be sought to promote interaction, particularly feedback from the OT&E to the developer. Combined testing would provide a very strong vehicle for this type of interaction. The Defense Science Board concluded "interaction among development test and evaluation and close contact with the user pays very important dividends in terms of money, time, and operational suitability".

C. INTEGRATED TEST PROGRAM

Another alternative available to the Program Manager for the ALGM T&E is the Integrated Test Program approach. The Integrated Test Program approach features performance of that amount of testing necessary to confirm compliance with specification requirements and verify operational effectiveness and suitability. Close coordination, interface and pooling of information/data by all T&E participants is necessary to cumulatively build the net data base with each successive program phase. Properly executed, the Integrated Test Program approach minimizes ALGM and other asset requirements. The Integrated Test Program differs from Combined Testing in that the DT&E and OT&E testing is not conducted together or simultaneously but is conducted in a fashion

similar to the Separate Test Programs in Series, exclusive of the repetition and redundancy and with an operational flavor provided by early, continuing OT&E participation.

1. Management Approach

The intent of the Integrated Test Programs approach is to work within the requirements and guidelines of OPNAVINST 3960.10 while vigorously controlling costs and schedule and because of this, much of the Management Approach information relative to the Separate Test Programs in Series in applicable. The descriptions of DT&E, OT&E and their respective phases are still apropos and utilization of contractors, participating field activities, and other support activities is still required.

The early stages of the program, prior to Milestone I, are critical to the success of the Integrated Test Program. It is imperative that the Program Manager or his designee for T&E, enlist the support and active participation of all T&E participants in the preparation of ALGM specifications appropriately couched in operational terminology, followed by preparation of the TEMP for CNO approval just prior to Milestone I. The Program Manager must make it clear to all T&E participants that repetition and redundancy are not usually conducive to a timely and cost effective T&E program. He must emphasize that testing is required to have an operational flavor beginning in the early stages and will be building block in form, with data to be accumulated through successive stages of the program. Having laid this groundwork, the three basic test programs of the Integrated Test Program appear as follows:

a. Contractor Program

DT-I through DT-III as described in section III C 1, i.e., the building block testing approach from major component to ALGM section and on to ALGM level culminating with Contractor Demonstration Tests, including:

(1) Part and component qualification, assembly, and sub-system tests (accelerated life, overstress, and design evaluation and qualification), sub-system and section integration and compatibility tests.

(2) ALGM system level performance tests on the ground (chamber tests), on board the aircraft, and in the captive carry mode concluding with several missile launches from aircraft,

(3) reliability demonstration for compatibility with specification requirements (ground and airborne testing for captive carry MTBF, launch and free flight to target reliability) at the required confidence levels,

(4) maintainability demonstration for compatibility with specification requirements,

(5) environmental and safety qualification (including electromagnetic compatibility) to verify compliance with specification design requirements.

OPTEVFOR and TECHEVAL personnel should support the Program Manager and contractor in establishing specification requirements responsive to the threat with user inputs which are representative of the operational environment. After early verification of adequacy, continuing effort must be expended to maintain compatibility with the operational

environment. OPTEVFOR and TECHEVAL should support the Program Manager and his participating field activity Technical Manager in reviewing for government approval all Contractor Demonstration Test (CDT) plans, test procedures, and test reports and should actively participate in monitoring contractor CDTs to assure technical compliance and operational adequacy.

b. TECHEVAL Program

Performed during the final sub-phase of DT-III and includes: ALGM system level performance tests both on the ground (chamber tests), on board the aircraft, and in the captive carry mode concluding with several launches, reliability data acquisition and evaluation as part of the ALGM ground and airborne testing, sufficient to confirm ALGM adequacy and readiness for OPEVAL but not a repeat of the Contractor Demonstration Test. The intent is to build on the Contractor Demonstration Test reliability data base, ALGM configuration permitting. Maintainability and supportability should be evaluated in concert with the testing described above. It is not necessary to repeat the Contractor's maintainability demonstration at this stage. Implementation of the foregoing TECHEVAL results in significant ALGM program cost savings over other T&E alternatives through conservation of T&E resources and schedule improvement.

c. OT&E Program

OT-II and OT-III, as described in section II C 2, is performed culminating with OPEVAL, which includes: ALGM system level performance tests on board the aircraft, on the ground and in the captive carry mode concluding with several missile launches, airborne data acquisition and evaluation of captive carry MTBF, and launch and free

flight reliability data as part of the ALGM ground and airborne testing. This should be sufficient to confirm operational effectiveness and suitability and when coupled with the accumulated applicable Contractor Demonstration Test and TECHEVAL data, should complete the development characterization of the ALGM and confirm its compliance with specification requirements and readiness for production. Suitable confidence limits should be employed and appropriate truncation techniques applied as necessary under the guidance of competent statistical support help to maintain statistical rigor.

Maintainability, supportability and other logistics related ALGM system characteristics as well as compatibility, operability, human factors, and training adequacy should be evaluated. Tactics development and refinement should continue as necessary.

d. FOT&E Program

OT-IV is performed as described in section IIIc.3 and under the Separate Test Programs in Series approach.

2. Applicable T&E Management Problems

Many of the problems facing the Program Manager are similar to those to be encountered in the prosecution of any T&E program. However, the nature of the Integrated Test Program and demands it makes on the Program Manager do create some unique situations. The spectrum of problems identified in section IV have some degree of applicability but redundant testing with duplication of facilities, personnel, and their related costs is clearly reduced in significance.

a. Planning

The Program Manager will have to exercise strong powers of persuasion to get the program T&E participants together with users early

and obtain the cooperation needed for planning vital to the structuring of the program budget and development of the baseline TEMP. This early cooperative effort will have to be sustained throughout the program to provide the impetus for implementation of the T&E program and for maintenance and updating of the TEMP and the T&E portions of the DCP. The Program Manager will have to plan the acquisition of the ALGM design disclosure documentation package carefully and provide for configuration management in a timely fashion. The ALGM design disclosure documentation package evolves with the design and is necessary to define and control hardware configurations, and changes thereto, while undergoing T&E. This will support and lend credibility to the test programs by assuring knowledge of what was tested and will ease the evaluation of the effectiveness of changes. Also, if hardware configurations are known and controlled, development of a credible test data base will be made easier. This will be a difficult problem to overcome because, in the past, according to NAVAIR, contractor, and participating field activity personnel, acquisition of the ALGM design disclosure data package has often been mishandled and not fully supported by Navy program sponsors and the Developing Agency.

b. Proliferation of Requirements

The Program Manager will still have to contend with problems due to requirements unique to certain participating field activities, test facilities, ranges and other agencies as indicated in section V A 2b. A strong early planning effort with full participation and cooperation from the T&E community providing clear delineation of the program to be conducted and participant's responsibilities with related budgets, should aid in the control process. The Program Manager requires the assistance

of higher Navy management and OSD in limiting the number of "special" management reviews of the T&E program as well as other aspects of the program. This should be identified as an issue early in the program and brought to higher management attention during early program reviews and when the T&E program is presented for approval at Milestone I. The NMARC report recognized this as a significant problem for the Program Manager, stating that, "his program is reviewed at various levels up through DoD by offices with little or no accountability. Hence, he can be "second guessed" by all concerned, yet he is the specific individual who must assign his assets in the most effective manner to execute the overall program" [Ref. 16].

c. Resource and Schedule Constraints

Scarcity of ALGM assets and test facilities, possibly impacting T&E schedules, should be no more severe than under the other T&E approaches and may actually be alleviated by the Integrated Test Program. Fewer total ALGM assets and hopefully, fewer facilities are involved but specific targets and/or target complexes will be in demand and range instrumentation taxed. Maintenance problems may result because of higher utilization rates.

Limited test flexibility and ability to conduct operational type testing on what primarily are still R&D oriented ranges will inhibit the user-evaluator's IOT&E effort. Bowes [Ref. 9] also found that a major portion of the physical resources utilized by OPTEVFOR for its operational evaluation are controlled by the Developing Agency. The Integrated Test Program approach provides the mechanism for the development of plans for the utilization of these limited resources by OPTEVFOR and the DT&E agencies. Lack of control of the major portion of the

physical resources required for OT&E (instrumentation, ranges, data processing centers, simulators, and test aircraft) appears to reduce the independence of OPTEVFOR.

d. Redundant Testing

As previously states in section VC, redundant testing will be virtually eliminated as a significant problem in the ALGM T&E process by implementation of the Integrated Test Approach. Performance, reliability and maintainability testing will not consist of repeated lengthy and costly demonstrations of compliance with design requirements but will be cumulative in nature, under conditions reflecting operational conditions agreed to in advance by all T&E participants. Credibility of the test base will have to be assured through proper test design and control, as well as early implementation of configuration management and a strong failure analysis and corrective action program. Implementation of the foregoing demonstrates a well thought out, plausible T&E approach, with reasonable test objectives and appropriate numbers of assets of known configuration with other necessary resources to progressively attain T&E objectives.

e. Management of Diverse Activities and Functions

The Program Manager will be severely tested as will the Navy's matrix organization in the implementation of the Integrated Test approach. The Program Manager must strive for early cooperation and acceptance by the participating NAVAIR design groups and test facilities, participating field activities, OPTEVFOR, and the contractor. The contractor may initially be balky when faced with the possibility of early exposure to ALGM test vehicles to at least a synthesized operational environment. Contractors and Navy Program Managers fear

that early, visible failures under anything approaching operational conditions, could result in program cancellation. Incorporation of operational requirements in design specifications will be difficult, requiring close coordination between all design groups and T&E program participants. The difficulty arises because of the limited success to date in translating operational requirements into terminology and units for inclusion in specifications for test and measurement [Ref. 20].

With regard to the TECHEVAL portion of the T&E program, the Program Manager may receive considerable opposition from within the NAVAIR T&E community and from PMTC because of the proposed reduced scope of TECHEVAL. However, when interviewed recently, the incoming AIR-06 (formerly the PMA for ARM missiles, possessing major acquisition experience) indicated that in his opinion, too much testing had been done in the past for testing's sake and that the T&E program has to be tailored to the overall weapons acquisition process. He also suggested that early planning was key and would enhance the program's stature with OSD.

3. Other Problems

The Program Manager will have to assure early efforts on the part of the potential ALGM users, OPTEVFOR, NAVAIR and contractor design groups, in the development of test envelopes with respect to the mission profile from which T&E test plans will evolve. Mechanical model ALGMs will have to be used for aircraft captive carry, laboratory environmental determination efforts, and compatibility with designated and potential user aircraft.

Another concern for the Program Manager will be the need to make DD(T&E) aware of the intended approach, prior to Milestone I if possible, and take the necessary steps to retain his understanding and concurrence

throughout the program. PMA-242 (the Anti-Radiation Missile Program Manager), in an interview, indicated that periodic detailed briefings to DD(T&E) have served to promote an understanding and acceptance of lower level testing, simulations, and the fact that the totality of the worth of an ALGM system should not be based on free flight performances alone. DD(T&E) may also require assurance of OPTEVFOR's independence and their continued ability to be objective, even though involved very early in the program and to the extent required.

4. Good Features

Implementation of an Integrated Test Program affords an opportunity to the ALGM Program Manager to alleviate the T&E impact on overall program costs and to exert better schedule control. The Defense Science Board indicated "there may be a potential to reduce the large demands of reliability and maintainability testing if the various agencies responsible for such testing could develop coordinated and integrated test plans. That is, factory chamber testing, developmental testing under operational conditions, and operating testing all provide opportunity for collecting R&M data" [Ref. 15]. The Integrated Test Program approach should preserve the distinct DT&E and OT&E purposes and assure that appropriate personnel are doing the testing required under each type of testing.

Greater involvement of OPTEVFOR should:

a. help to alleviate problems with regard to development and review of incorporation of operational requirements into design specifications and translation of these requirements into tests,

b. bring consistency in terms of test requirements, test methods, and test data acquisition and interpretation,

c. make it easier to stay abreast of the environment in which the threat will be encountered, and

d. help make DT&E test results more credible and acceptable to DD(T&E) and the DSARC committee.

The Integrated Test approach should also help to alleviate Defense Science Board concerns with regard to repetitive and redundant testing and NMARC concerns regarding an uneconomical amount of testing and testing beyond the capability of the hardware. And finally, the Integrated Test approach should provide an auditable trail of requirements versus performance which has been of great concern to both DD(T&E) and the NMARC.

D. SYSTEM LEVEL FUNCTIONAL TEST PROGRAM

The last alternative or approach to be considered is that of the System Level Functional Test Program. Proponents of this method require that testing be accomplished at the ALGM system level on the assumption that the ALGM system and all of its parts can satisfactorily demonstrate required capabilities and be qualified as a unit. This approach is usually suggested when the item to be tested is not very complex, as a viable alternative in a crisis situation, or as a "get well" remedy when schedule slippage and cost growth is first detected in DT&E. The intent in the testing mode is to perform as few tests as possible, conserve ALGM test assets, have the shortest possible development T&E schedule, with minimum cost. Unfortunately, avionics equipments ("black boxes") are most often cited as representative of hardware qualified for service use in this fashion rather than existing ALGMs; also, most of the equipments cited were developed under quick response contracts during hostilities in southeast Asia and were few in number.

This approach is an extremely optimistic one. It would appear, on the surface, to reduce ALGM asset requirements, provide a shorter development schedule than any of the others considered, and therefore be cost effective.

1. Management Approach

The management approach is quite similar to that of the Separate Test Programs in Series or Combined Test Programs with the exceptions as follows:

a. Contractor Program

The contractor portion of the DT&E phase essentially discards the building block approach to hardware development, i.e., seeks to avoid the individual performance, reliability, and environmental qualification of critical parts, components, and assemblies. This approach also avoids or minimizes sub-system testing and tries to accomplish interface evaluation and compatibility verification at the time ALGM or system level testing is conducted. Performance, reliability, and environmental qualification (i.e., Contractor Demonstration Tests) are performed at ALGM level, to ALGM system specifications.

b. TECHEVAL Program

The TECHEVAL is planned and conducted as with Separate Test Programs in Series (section VA 1 b) but without the prior testing and verification foundation usually acquired through the contractor program.

c. OT&E Program

OT&E is planned and conducted as previously indicated (i.e., Separate Test Programs in Series, section VA 1 c).

2. Applicable T&E Management Problems

a. Planning

Planning is extremely limited and optimistic to begin with (testing at ALGM level only and no contingency plans for failure) and problems which occur at ALGM system level are much more difficult to diagnose, analyze, and correct. Failures and related delays, redesigns and corrective action assessments with retests can consume significant amounts of time, impact schedule and costs severely, and cannot be planned for.

The planning problem is even more basic than the previous paragraph would indicate. In today's acquisition environment, the Program Manager and his staff would probably encounter problems in arriving at an agreed upon TEMP approach with COMOPTEVFOR and doubtless would experience great difficulty in getting DD(T&E) acceptance and/or concurrence to this approach unless there were unusual mitigating circumstances, i.e., national emergency, significant technological gain that might be lost without a maximum concurrency type of approach, or some similar situation of urgency.

b. Proliferation of Requirements

Problems here are essentially the same as with Separate Test Programs in Series.

c. Resource and Schedule Constraints

Even with the limited asset approach indicated, certain major components and sections of the ALGM will require at least limited qualification and man-rating (proof of safe-for-launch from manned aircraft) prior to introduction into ALGM system level testing. One shot devices, batteries, fuzes, warheads and propulsion systems

(rocket motors) fall into this category. Until the limited qualification is accomplished, system level testing will be inhibited significantly.

With the optimistic limited asset situation, there is little margin for error. There could be a severe resource problem with major schedule impact, as a result of failures, that could virtually bring the program to a standstill. Without adequate resources (ALGM assets), problem evaluation, corrective action determination and re-test cannot proceed. A requirement to build additional hardware (i.e., re-start fabrication process) could effectively cause termination of the program. Finally, according to the Defense Science Board [Ref. 11], hardware problems, a shortage of funds and schedule problems inhibits thorough risk assessment when problems occur. Without the risk assessment, the Defense Science Board says the DSARC will be faced with complex technical issues requiring a detailed review and may not permit progression to succeeding milestones.

d. Redundant Testing

These problems will essentially be the same as encountered with Separate Test Programs in Series (section V A 2 d).

e. Management of Diverse Activities and Functions

Accent on minimum testing may create problems with certain activities and functions as discussed under V D 1 a; otherwise, problems will be similar to those of Separate Test Programs in Series.

3. Other Problems

It is virtually impossible to stress all parts in an ALGM to system design limits much less get all parts to function as they would under mission conditions, while under system test conditions, due to

testing limitations posed by laboratories, facilities, and equipment. Therefore, part, component, assembly, sub-system tests leading to a number of system tests is the optimum way to proceed. Even with the building block approach, failures occur, but with testing at ALGM level only there will be failures that will be extremely difficult to fault isolate and some may even go undetected until subsequent phases of testing where the true cause of failure may be masked.

The 1974 Defense Science Board report [Ref. 14] stated, "Significant time and money will be saved if each component, each sub-system, and the full system are all tested as thoroughly as possible in the laboratory". The report went on to say, "Whenever field testing is expensive compared with laboratory and simulation testing (as in missile or aircraft/missile flight testing), such testing should be conducted primarily for verification of design parameters or design performance, rather than to see whether or not a particular component or sub-system will work".

4. Good Features

As seen in sections V D 2 and V D 3, this approach suffers from its departure, in the DT&E phases, from the proven hardware building block approach advocated by the Defense Science Board and has a high probability of failure. There are no known or recognizable features significant enough to overcome the inherent deficiencies in this testing approach. It does not appear to provide the basis for a sound development approach and it increases the acquisition risks greatly.

In this section, four of several possible alternative program management approaches to T&E programs for ALGMs have been presented. Each alternative was analyzed in terms of its management methodology, applicability of management problems identified in section IV to each alternative, and other problems deemed relevant and unique to that alternative. Favorable features were also identified as part of the analysis for each alternative. These analysis findings, in terms of positive and negative features, are summarized in Table I. Any one of the initial three alternatives would be acceptable given the proper circumstances and resources.

TABLE I. Alternative ALGM T&E Program Features

ALTERNATIVE	POSITIVE FEATURES	NEGATIVE FEATURES
Separate Test Programs in Series	• More testing time for proofing and debugging • Uses very strict building block test approach; i.e., low risk approach • OT&E testing quite independent • Longer program may reduce decision risk	• Everybody tests independently • High cost, long sch'd, most assets req'd • Little interplay between DT&E and OT&E • OT&E (OPEVAL) may be subjected to resource and schedule crunch
Combined Testing	• Testing has operational flavor • Strong interaction between OT&E and developer • Forces early involvement of OT&E • Should improve schedule, lower T&E cost • Improves utilization of T&E assets • Redundant testing reduced	• TECHEVAL and OPEVAL not combinable • Difficult to obtain both DT&E and OT&E data from same test; controlled vs noncontrolled environment; objectives different • Early planning mandatory; T&E execution difficult • DT&E evolutionary build-up approach to testing contrary to OT&E system approach
Integrated Test Program	• Conserves schedule • Reduces repetition and redundancy and optimizes utilization of T&E assets • Uses building-block test approach; i.e., lower risk • Operational influence in planning • Resource cost, scheduling constraints eased • Testing has operational flavor, test data base cumulative, OT&E independence preserved	• Early planning mandatory; cooperative efforts required throughout development • Must change TECHEVAL standard operating procedure • Management of diverse activities and functions severely tested; demands on Program Manager high • Proliferation of requirements still feasible
System Level Functional Test Program	• Provides shorter development schedule • Potential of reducing program costs • Reduces asset requirements • TECHEVAL and OPEVAL preserved as currently performed	• High program risk, probability of failure • Not all parts of system tested, failures difficult to diagnose, some not detected • Not sound basis for development; deviates from building-block approach • Highly success oriented, no contingency planning; a failure can severely impact program cost and schedule

VI. PROPOSED TEST PROGRAM STRATEGY

Bowes [Ref. 9] cited less than optimal utilization of the Navy's T&E resources and found that the prevalent belief that "more testing is better, so let's continue to do more and not worry so much about the duplication" was a simplistic and costly solution to the Navy's T&E problem. Changes have occurred in Navy T&E subsequently, but current OSD, CNO, and NAVMAT directives and instructions have not been implemented by directives and instructions from the Developing Agency most responsible for Navy ALGM development. In the absence of specific promulgated directives and guidelines and direct ALGM program participation by AIR-06 personnel, Program Managers are still faced with the beliefs and perceptions cited by Bowes.

Consideration of the alternative approaches to conduct of the T&E program for ALGMs in section V indicates that, on balance, the Integrated Test Program approach provides the best opportunity for the ALGM Program Manager to conduct an adequate, cost-effective, T&E program while working within the requirements and guidelines of OPNAVINST 3960.10. Figure 7 presents the organizations, and their respective functions, which must come together early in the program to assist the Program Manager in developing and implementing the ALGM T&E program.

The purpose of this section is to build upon the Management Approach portion of section V C and propose a "Test Program Strategy" which will aid ALGM Program Managers in the development and implementation of an Integrated Test Program. The proposed strategy will preserve the DT&E

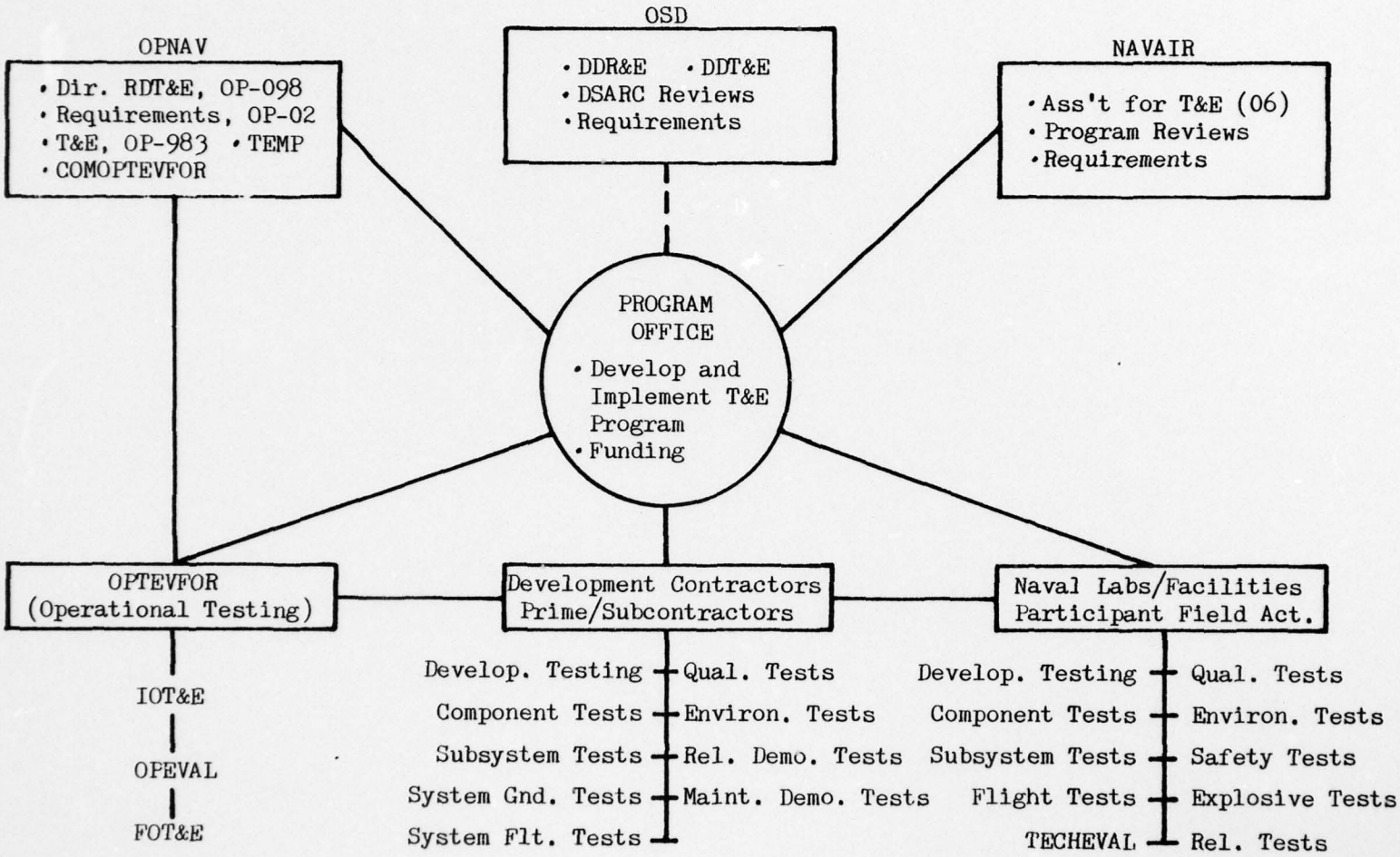

Figure 7. ALGM T&E Organizational Interfaces

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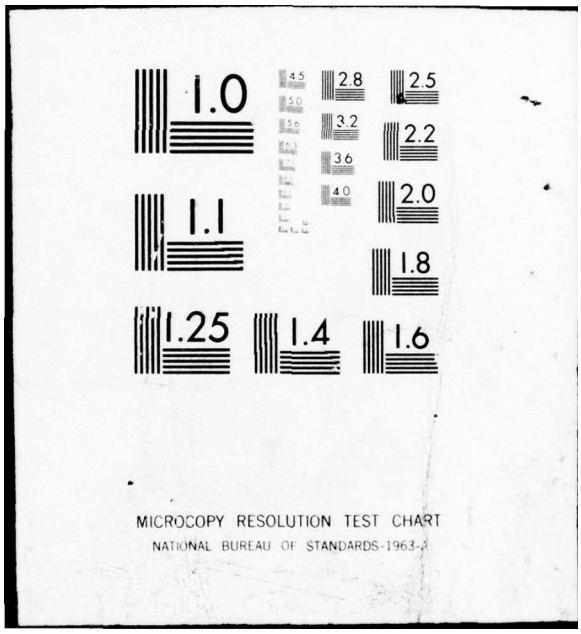
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and OT&E purposes while reducing repetitive and redundant testing, provide an auditable trail of requirements versus performance, and help to bring consistency to ALGM testing in terms of test requirements, test methods, and test data acquisition and interpretation. The Integrated Test Program, to which the proposed strategy is applicable, is as depicted in section V C 1 and consists of the Contractor, TECHEVAL, OT&E, and FOT&E programs as outlined.

A. ELMENTS OF THE PROPOSED STRATEGY

The proposed strategy to be employed in an Integrated Test Program consists of consideration and implementation of a number of activities under the major ALGM elements of:

1. Planning
2. Types and Categories of Tests and Resource Requirements
3. Responsibility for and Conduct of Tests
4. Information Flow, Assessment and Reporting

The necessary actions to implement the strategy are developed in subsequent paragraphs.

1. Planning

The purpose of the Integrated Test Program approach, as it is with any test program, is to perform an optimum amount of testing (i.e., that amount necessary to confirm compliance with specifications and operational effectiveness and suitability) and no more. Repetition, duplication, and redundancy are to be minimized. Hence, planning has been emphasized as a critical element in any T&E program (section III H) but as pointed out in section V C 2, it is especially critical to the Integrated Test Program approach because of the very close coordination and interface required of different, widely dispersed organizations and

because integration or pooling of test data is necessary to successfully demonstrate compliance with test objectives while utilizing minimum ALGM assets and other resources.

Areas of consideration where actions should be taken to improve early and follow-on planning and also to increase the overall test and evaluation efficiency are as follows:

a. Operational Requirements vs Design Specifications

A very important facet of the early planning strategy requiring user participation or representation is the development of operational or functional requirements suitable for inclusion in design specifications to which contractor designed and built ALGM hardware will have to perform. These requirements become the basic criteria for the T&E program and for acceptance of T&E results. Tactical employment of the ALGM should be considered with ample resources brought to bear to develop a mission profile for inclusion in the specification. The mission profile should reflect ALGM operating duty cycles based on tactical usage and should also consider the peacetime vs wartime scenario where expenditure rates effect the number of cycles (catapult launch, captive carry, and arrest landings) that ALGMs may be subjected to. The mission profile should also reflect consideration of the ALGM launch envelope, aircraft maneuvers, cockpit workload, and interface with other systems on the user aircraft. Aircraft, launcher, ALGM interfaces should be considered and user experience in these areas should be reflected in the design specifications. Finally, the design and operational or functional requirements must be translatable into test requirements which are agreed upon by the T&E participants and can be employed in DT&E and OT&E phases of the program to confirm ALGM compatibility with design requirements and military worth and utility.

b. Test Hardware Considerations

The quantity of ALGM test assets required to support the T&E program and the amount of time provided for successful completion of all testing is critical to program success. Early planning must be performed to provide sufficient time and resources for operational tests, particularly the IOT&E phase, because the production and deployment decision is based upon IOT&E results. Correspondingly, later in the program, the Program Manager should not lose sight of the continuing need for test articles. There have been circumstances where, for various reasons, the technology has had to be pushed rapidly; the higher risks involved have required more thorough testing and/or greater resources. These programs, usually had to have more assets and have been expanded to longer times. Typical hardware and facility requirements for an ALGM program are addressed in VI A 2.

c. Test Facilities and Instrumentation Requirements

Before Milestone I, the test facilities and instrumentation requirements to conduct tests should be identified along with a tentative schedule of test activities. AIR-06 personnel must play a key role in this effort because of its relationship to the Navy's Major Range and Test Facility Base (MRTFB). They must keep in mind that OPTEVFOR is totally dependent upon others for their test facilities and instrumentation and that, historically, test ranges have inhibited operational testing because of their primarily R&D orientation and inherent lack of operational flexibility. The capabilities of the test ranges and the adequacy of the facilities and instrumentation should be verified; alternative approaches considered (i.e., other ranges should be identified) and the need for instrumentation improvements or changes be

identified early in the program. Range and instrumentation limitations may place constraints on ALGM flight testing and targets warrant special consideration; most ALGMs cannot be adequately tested without targets that realistically simulate the threat. Considerable lead time may be required to provide the required target support; therefore, target requirements to support the tests must be identified early.

d. Test Configuration Control

Proper ALGM and component configuration identification and control throughout the test program is essential to the creation and maintenance of a credible test data base. If it is not known what was tested, the test results are not too significant. Early planning will be required to develop the appropriate means of recording ALGM and/or component configuration (i.e., log books or similar methods) and for relating the configuration to test results. The recording means must be compatible with different working environments and users, i.e., laboratory and test range, contractors, participating field activities, and OPTEVFOR. Conditions and component configuration during development tests should be determined by the primary objectives of that test.

Whenever a non-operational configuration (e.g., ALGM with inert warhead and/or rocket motor) is dictated by early test requirements, tests should not be challenged by the fact that the configuration is not operational. Where tests are run with substitute parts, procedures should provide for recording the fact and ensuring that necessary retesting is done with the correct components. When testing is delayed because of the non-availability of critical sub-system components, off-the-shelf interim components may be used as substitutes until the proper components are available. As long as the off-the-shelf components can

function acceptably within a defined range of interest, the rest of the system can be tested, thereby facilitating the progress of the test program. On the other hand, demonstration and acceptance tests, as well as tests intended to evaluate performance under operational conditions, should always be conducted under conditions as close to those anticipated in operations as possible, including present ALGM configuration.

The reliability data base is especially susceptible to problems created by poor configuration control. To pool or group reliability data, as desired with the Integrated Test approach, the hardware tested must be from a homogeneous population. This determination of homogeneity through exercise of change control will require particular care once ALGM prototype and pilot production hardware becomes available for testing and demonstration in DT-III and OT-III. If change control is ineffective or major design changes are dictated, there may be no other alternative than a formal demonstration test program at a later point in the program but prior to the release to production decision (Milestone III).

e. Updating IOT&E Planning

The early planning required to support initial DCPs and Milestone I will require frequent updating to keep pace with a dynamic program. The participating field activity Technical Manager and contractor will usually take the lead in maintaining the currency of the DT&E program but the Program Manager or T&E coordinator may have to provide the stimulus for the update of IOT&E planning during the early R&D phases. Few ALGM system programs have had adequate user participation with the desirable continuity of personnel to minimize the problems of transition from DT&E to OT&E to deployment/utilization. The early evaluations may be largely restricted to mock-up exercises and user-evaluator participation in the R&D. One of the user-evaluator's major activities should be

to use the day-to-day exposure to the R&D system as on-the-job training in preparation for the IOT&E program. Good IOT&E planning should cover the allocation of manpower spaces or billets, assignment of personnel and their training, equipment provisioning (including at least preliminary technical manuals), ground support equipment, spare components, launchers, and missiles. IOT&E planning may also include plans and/or requirements for instrumentation, ground tests, and flight tests of important profiles and will also provide for data collection, analysis, and reporting. The latter assumes even greater significance when the Integrated Test Program approach is followed and the reliability data base is to be cumulative during crucial DT&E and IOT&E tests and evaluations.

f. Computer Software

As ALGM designs have become more sophisticated, utilization of mini-computers has become more commonplace and the problem of T&E of the central processor unit and the associated software has grown. The Program Manager or T&E coordinator must ensure that software products are tested appropriately during each phase. Even though the computer is a critical component of the ALGM, software has often been developed more as an add-on than as an integral part of the overall system. Software requirements need the same T&E consideration as hardware requirements in the early program phases. It is more difficult to determine the status of completion of various phases of the software program (as compared to hardware programs), so it is important to explore how contractors develop and test software programs. No standard procedure seems to be available within DoD for orderly T&E of software items, yet the increased percentage of ALGM development cost introduced by software makes the

establishment of a suitable procedure a matter of utmost importance. Any new procedure should provide for orderly program definition and for continuous testing and monitoring of the software program development, to provide assurance that adequate, efficient, reliable operation will be possible. Annex A to the Defense Science Board Report provides specific guidelines for tracking the development of computer programs essential to the functioning of weapon systems [Ref. 14].

g. System Reliability

Inability to meet specified reliability requirements and poor operational reliability has characterized many recently developed ALGMs. It should be emphasized that poor reliability is not only a function of component failures but also is influenced greatly by failures induced by poor hardware design, poor software design, operator errors, wear out of mechanical components, and failure to appreciate the severity of operational environmental conditions. The Program Manager or T&E coordinator must require that realistic operational as contrasted with design (inherent) reliability requirements be defined, in terms of completing a mission of specified duration under stated mission (environmental) conditions, and that testing adequate to demonstrate achievement of these requirements be accomplished successfully.

It is necessary that the improvement of reliability be a planned activity during the development phases of the program, that it be monitored during these phases, and its achievement proven by testing prior to the major production decision. Interim goals must be established, with tests devised based on these goals, to allow tracking of reliability growth throughout the program. This progressive attainment of interim goals toward the required reliability for the ALGM must be reviewed at critical points or milestones of the program, as follows:

(1) At the time the Program Manager requests initiation of engineering or full-scale development (Milestone II), he should be prepared to show a realistic reliability growth plan with sufficient test time and resources to achieve the program reliability requirements from initial and interim goals to final requirement.

(2) At the time the Program Manager requests initiation of limited production (Milestone II A), he should be prepared to show:

(a) By contractor demonstration test results, the system has achieved, at a reasonable confidence level, the expected percent of the reliability requirement for the ALGM, where both confidence level and percent achievement are appropriate to the program at this stage, i.e., tracking projected reliability growth rate.

(b) There still remains in the development program sufficient ALGM system testing time to carry on reliability growth from the point achieved to the program reliability requirement.

(3) At the time the Program Manager requests authorization for full-scale production (Milestone III), he should be prepared to show:

(a) By contractor demonstration and accumulated TECHEVAL and IOT&E test results, the ALGM system has achieved, at a reasonable confidence level, the program minimum acceptable reliability requirement.

(b) A management plan, test plan, and funds to utilize the remaining test time in the development program for a vigorous program of reliability growth.

(c) A plan for some of the earliest production missiles to be allocated to early fleet test programs for reliability and life tests. These ALGMs should be required to accumulate many more ramp exposure hours and captive flight hours than usual prior to launch. In this fashion, early fleet test missiles can provide confirmation of ALGM reliability or provide early indications of production problem areas and possibly preclude dangerous situations or stand-downs of important capabilities.

h. Environmental Determination Effort

To confirm the operational environmental requirements contained in ALGM specifications and the defined mission profile and to support the development laboratory tests and operational tests, thorough measurements should be made, as early as hardware permits, to determine the actual environment in which the ALGM components must live during the transportation, captive flight, launch and free flight phases of the ALGM life cycle. These environmental measurements should be conducted during advanced development preferably and no later than early engineering development, because of the potential impact on the basic ALGM design and on the test programs. Funds, hardware, and necessary time should be provided for the measurement effort. In-flight environments, especially vibration, temperature, shock and stress imposed during the operational use of the ALGM, should be measured and documented under operational conditions using an instrumented ALGM. The captive flight measurements

should be utilized to structure ground environmental and reliability tests for demonstration of compatibility with captive flight requirements under controlled laboratory conditions. This has been done successfully on several recent ALGM programs (e.g., D-2 version of Standard ARM, AIM-9L Sidewinder, and the Air Force's Maverick).

i. Test Plan Coverage

It is important that test plans prepared by the different T&E participants support the objectives of the Integrated Test Program by assuring compatibility and credibility of data bases so that results are integrable or capable of being pooled, configuration identification and control so that it is known what was tested, and by assuring testing is not repetitive or redundant and that the "right" people are doing the testing. The Program Manager or the responsible reviewing activity acting for the Program Manager, should further assure that sub-system and ALGM system test plans are compatible with pre-established milestones and goals for ready assessment of program progress at a later date. Every test plan should reflect the approved TEMP where appropriate and include as a minimum, clear statements regarding:

(1) The overall purpose of the test

(2) Critical issues with respect to operational requirements

(3) The major test objectives

(4) The schedule of test milestone events

(5) The major resources required

  (a) Test environments, facilities, and instrumentation

  (b) Operational environment

(6) The organizations which will conduct the test program

(7) The analysis and evaluation approach

(8) Data acquisition and analysis responsibilities

(9) Reporting of failures, failure analysis responsibilities and procedures regarding resumption of testing

Planners should ensure that the schedule will accommodate problems and that clear, well-defined milestones for review and commitment to the next phase have been defined.

The implementation of the Integrated Test Program approach changes the traditional role of the TECHEVAL agency by minimizing additional environmental testing as a result of previously performed contractor demonstration tests and limiting the reliability testing to that supporting the ALGM technical performance evaluation (i.e., ground testing on the aircraft, captive flight tests, launch and free flight) and contributing to the overall reliability data base. To further assure compatibility with the Integrated Test Program approach and the consistency and adequacy of the data base, the TECHEVAL test agency should be required to prepare and submit to the Program Manager, for approval, formal test plans and procedures followed by a formal test report at the conclusion of TECHEVAL. OPTEVFOR personnel should support the Program Manager and his participating field activity Technical Manager in reviewing the test plans, procedures, and report and should actively participate in monitoring the TECHEVAL itself to assure compatibility with operational requirements and consistency of data base.

2. Types and Categories of Tests and Resource Requirements

a. Types and Categories

The types and categories of tests relevant to ALGM T&E are discussed in section III.C and basically reflect the DT&E/OT&E structure of OPNAVINST 3960.10. Figures 8 and 9 depict DT&E and OT&E,

TEST CATEGORY	TEST SUB-CATEGORY	PHASES
1. Engineering development and design support tests	1. a. Performance tests [Lab (bench), flight line, captive flight, launch and free flight].	DT-I through DT-III.
	b. Integration and compatibility tests.	DT-I, DT-III.
	c. Environmental tests [Environ. survey (mechanical models), environ. shakedowns, environ. evaluation (EET).	DT-I through DT-III.
	d. Reliability tests [Lab (failure) modes tests, rel. growth (test, analyze, and fix TAAF) - Operational (captive flight, launch and free flight)]	DT-II, DT-III.
2. Components/parts qualification tests	2. Critical component and non-standard parts qualification (i.e., batteries, gyros, RF components, IC's)	DT-III
3. Contractor Demonstration Tests (CDTs) - ALGMs (for specification complicance)	3. a. Environmental and safety qualification (DPT/QT).	DT-IIIB
	b. Reliability demonstration [Lab (simulated operational captive flight)].	
	c. Maintainability demonstration.	
	d. First article configuration inspection.	
4. TECHEVAL	4. a. Performance tests (flight line, captive flight, launch and free flight).	DT-IIIB
	b. Reliability tests (flight line, captive flight, launch and free flight).	
	c. Supportability evaluation (maintainability and logistics related to a/b).	

Figure 8. ALGM DT&E Tests.

TEST CATEGORY	TEST SUB-CATEGORY	PHASES
1. IOT&E	1. a. Development assist-support DA for planning and tests during validation phase.	OT-I, OT-II.
	b. Operational assist-project assignment for assessment of program worth prior to full-scale development decision.	OT-II
	c. Test monitoring and assistance-project assignment to limited active participation and test review and monitoring including TECHEVAL surveillance.	OT-III
2. OPEVAL	2. OPERATIONAL EFFECTIVENESS a. Performance tests (flight line, captive flight, launch and free flight). b. Reliability tests (flight line, captive flight, launch and free flight). OPERATIONAL SUITABILITY c. Maintainability, supportability, compatibility, operability, human factors, training adequacy, tech. pubs.	OT-III
3. FOT&E	3. a. Evaluation of fixes incorporated in ALGMs. b. Fleet introduction - "lead the fleet program". c. Special reliability tests for early field assessment.	OT-IV

Figure 9. ALGM OT&E Tests.

respectively, for the Integrated Test Program approach. Sub-categories of tests are identified and the suggested phase for performance of the test is indicated. This approach as depicted, is in consonance with the Defense Science Board recommended hardware building block approach and limits redundant testing between the contractor, TECHEVAL agency, and OPTEVFOR. The common thread, in terms of testing, between the participants is obtained through tests performed on board the aircraft, on the flight line, during captive flight, and the launch and free flight to the target to determine that the test vehicle meets its basic technical requirements. The strategy, when implementing the Integrated Test Program approach, is to optimize the acquisition of not only performance data but also environmental, reliability, maintainability, operability, and human factors data by appropriate planning, design of the tests, and participation by user-evaluators as well as the developing agency. Under conditions, with appropriate configuration management in effect and where no major re-designs after prototype development ALGMs are fabricated, the contractor performance tests conducted under operational conditions should yield data that is integrable with TECHEVAL and OPEVAL data. The data, acquired under these conditions, is that also relevant to the ALGM acquisition decision process and most desired by DD(T&E) for its review and presentation to the DSARC, because it reflects progressive attainment of reliability goals and, ultimately, specified requirements under operational conditions [Ref. 14]. It also provides information relative to ALGM maintainability and operability and can also yield much data useful for human factors analysis (e.g., poor handling characteristics, poor placement of controls and readouts).

b. ALGM Models

Figure 10 depicts the different configurations of ALGMs that will be required during the different phases of the development program. The tactical ALGMs (live warhead) will be primarily used during OPEVAL and will also be utilized to a limited extent during TECHEVAL and contractor testing. This limitation is due primarily to the need for acquiring telemetered performance and environmental data with an instrumented test section throughout the DT&E period but also is due to the difficulty and expense of conducting warhead shots and the paucity of target assets. Guided Test Vehicles (GTVs) are used to evaluate full seeker and control section capabilities in captive and free flight with the aid of the instrumented test section. Particular emphasis is directed toward seeker/control interface and launch and guidance characteristics to the target. Flight Test Vehicles (FTVs) are used to evaluate aerodynamic features and flight control and autopilot designs, and usually do not include a complete or functional ALGM seeker section. Static Test Vehicles (STVs), featuring an inert warhead and rocket motor but with full capability seekers and control sections, are intended for extended periods of laboratory investigation and testing, i.e., environmental evaluations and tests and reliability growth testing. The Environmental Determination Vehicle (EDV) is specially instrumented to acquire temperature, vibration, shock, and acoustic data during captive flight on representative user aircraft. The same EDV will be used in the laboratory to simulate in-flight conditions and to develop environmental and reliability test criteria and should be available throughout the development program in the event of application to other user aircraft or major internal ALGM changes occur. Dummy ALGMs are used primarily for handling tests, container tests, evaluating interfaces, and static displays.

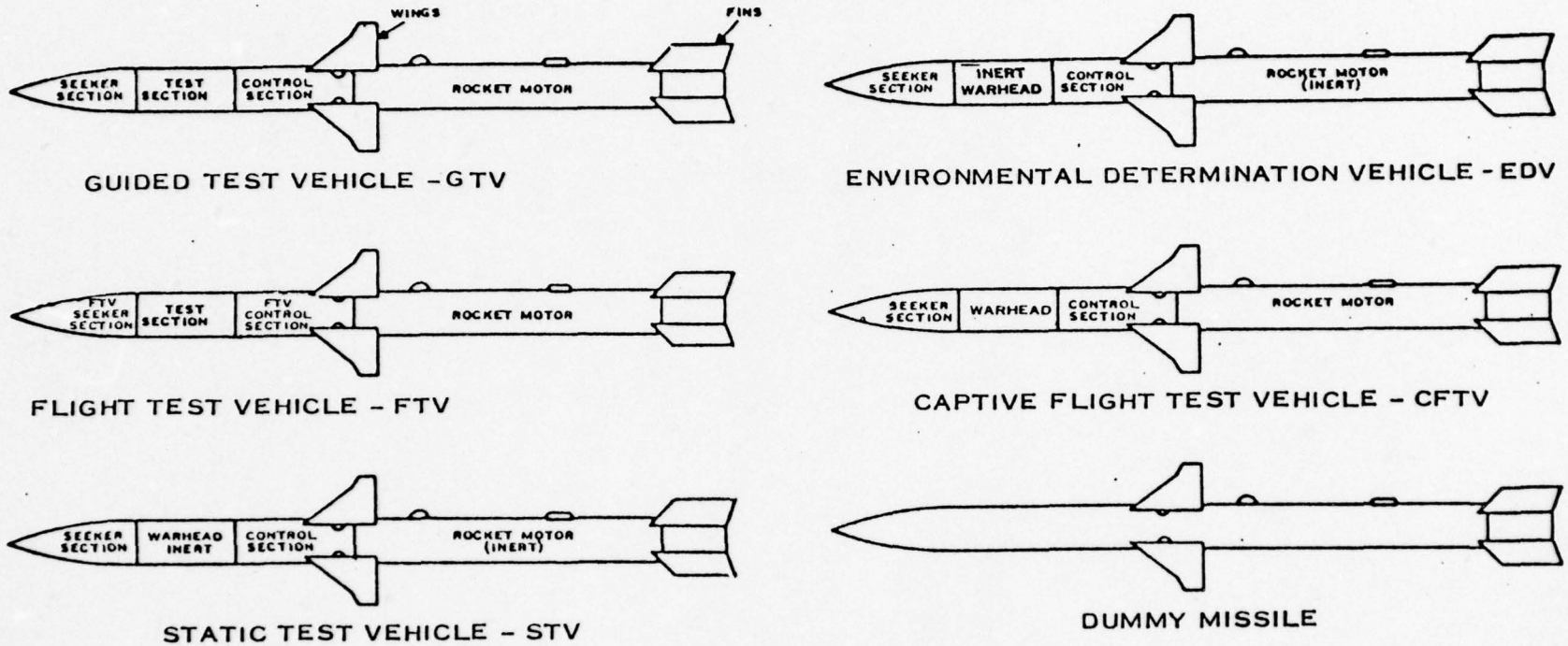

Figure 10. Development Test ALGM Configurations

c. Suggested Test Sequences/Flows

Figures 11, 12, and 13 provide suggested test sequences/flows for the contractor tests, TECHEVAL, and OPTEVFOR, respectively, to maximize the impact of the Integrated Test Program approach. A sequence/flow is not shown for DT-I because during this experimental period test sequence/flow is normally unstructured, has very few test assets, and usually features the use of hybrid ALGMs. For example, a recent Anti-Radiation Missile (ARM) program used an experimental seeker and parts of Sparrow and SHRIKE missiles along with a SHRIKE rocket motor for its early captive flight and FTV investigations.

Also shown within the individual activity blocks are typical ALGM asset quantities for that particular group of activities. Such asset quantities should normally provide adequate numbers for required tests yet retain a modicum of flexibility in the event of test failure or other setback. For example, 14 advanced development ALGMs are shown distributed as follows: 10 for captive flight, launch and free flight testing, 2 for environmental survey tests followed by failure mode testing, and 2 for environmental determination flights and laboratory confirmation testing.

The important features to be observed from the Integrated Test Program approach are:

(1) Progressive attainment of goals and requirements by the appropriate agency utilizing optimum assets.

(2) As shown in Figures 11, 12, and 13, TECHEVAL and OPTEVFOR personnel participate in the contractor test effort, and OPTEVFOR participates in the TECHEVAL test effort to provide the proper operational user-evaluator influence on test structuring and performance.

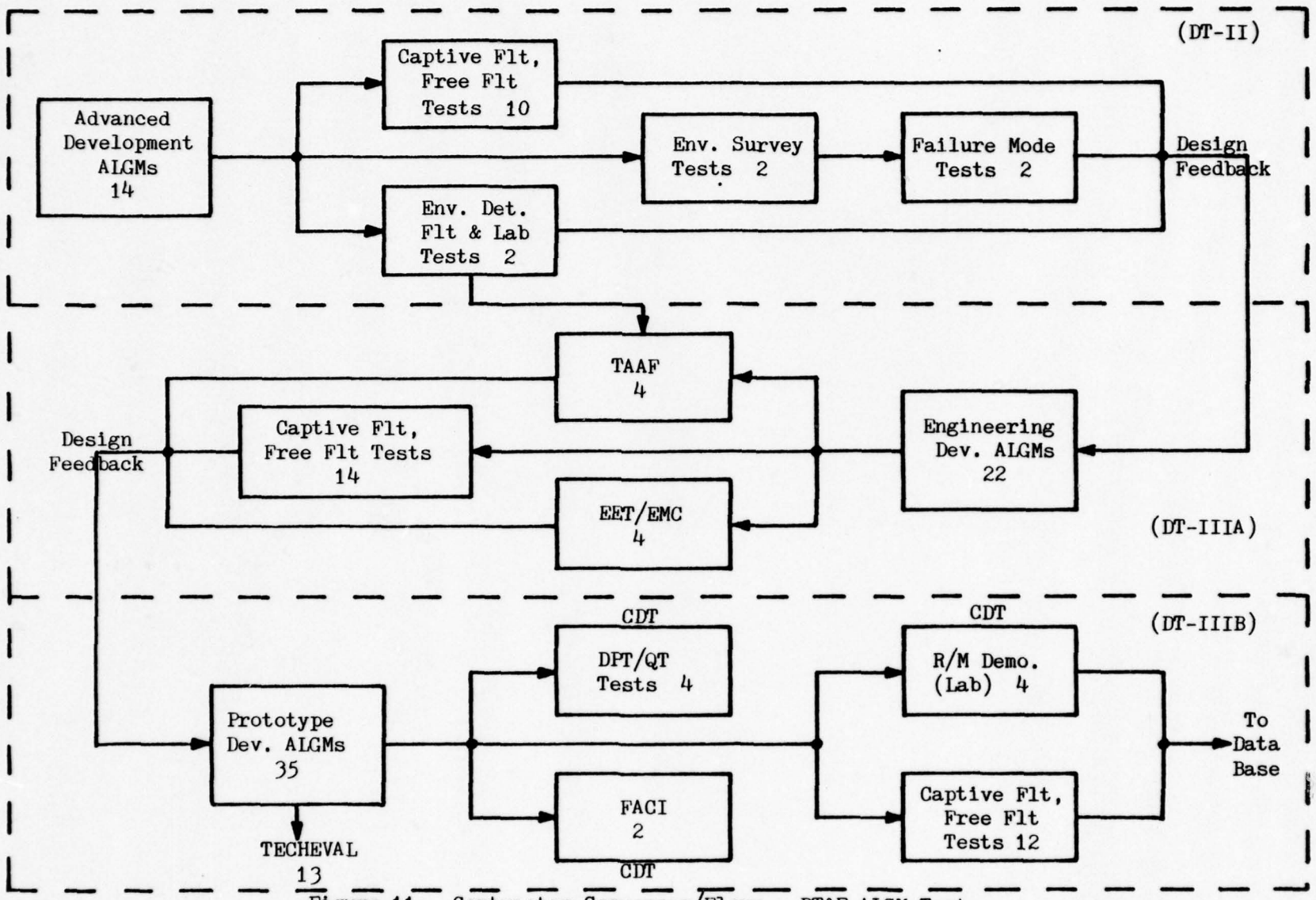

Figure 11. Contractor Sequences/Flows - DT&E ALGM Test

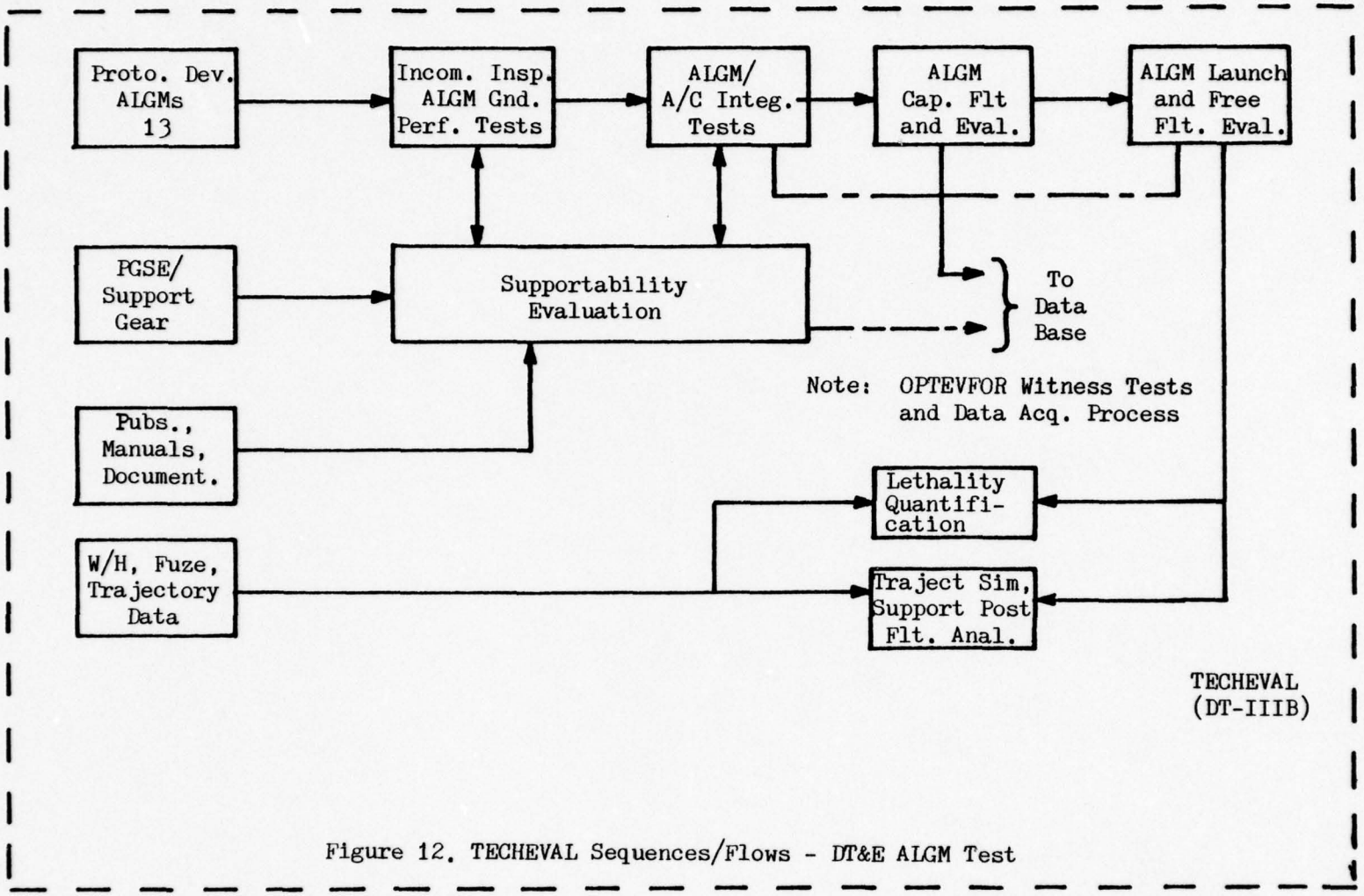

Figure 12. TECHEVAL Sequences/Flows - DT&E ALGM Test

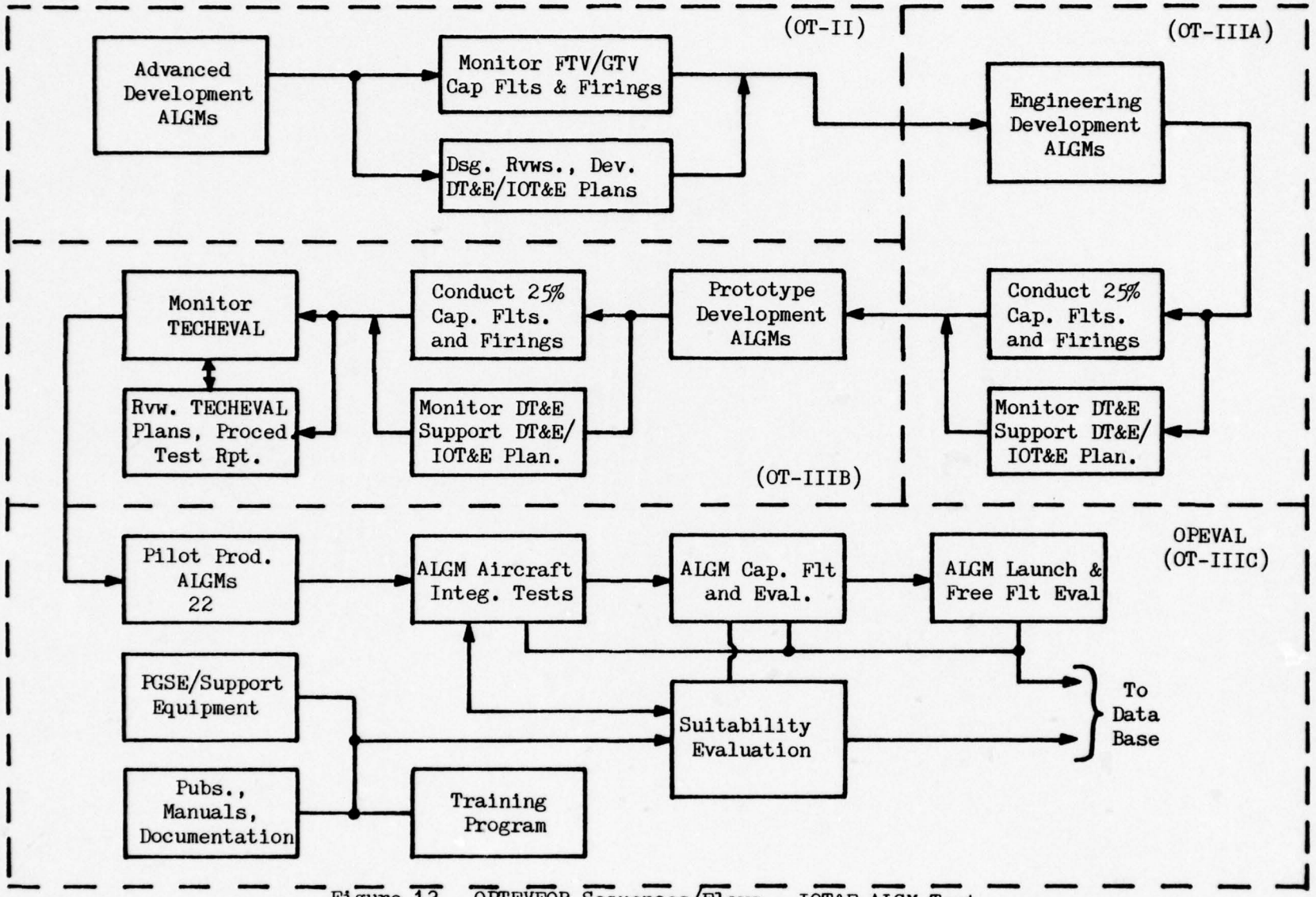

Figure 13. OPTEVFOR Sequences/Flows - IOT&E ALGM Test

(3) The contractor does what he has been contractually obligated to do with performance of development tests and Contractor Demonstration Tests (CDTs).

(4) A controlled, consistently planned, executed and acquired data base is established with the CDTs and built upon by TECHEVAL and OPEVAL with an increasing operational flavor through TECHEVAL and OPEVAL (where only tactical ALGMs are used).

(5) The TECHEVAL role is modified and limited to confirming ALGM specification compliance with ground tests on the aircraft and captive flights, launches and free flights and also performs a supportability evaluation (no duplication of already accepted laboratory environmental tests or reliability tests).

(6) Failure reporting, analysis, and corrective action determination and verification criteria should be uniformly applied and implemented throughout the development program by the Program Management staff.

d. Resource Requirements

ALGMs cover a broad spectrum from Short Range Air-to-Air (SRAAM) to High Speed Anti-Radiation Missiles (HARM) with air-to-air and air-to-ground capabilities. Many different kinds of facilities, chambers and targets or target simulators are required to support these ALGM T&E efforts. Because of this wide dispersion of requirements, the resource requirement will first be presented in a general discussion framework and then requirements for a typical ALGM program will be shown. Generally, resource requirements for ALGMs exclusive of T&E personnel requirements encompass the following:

(1) Contractor facilities and chambers for sub-systems and ALGM system level performance, structural, and a full range of environmental tests. Figure 14 is typical of the environments to which ALGMs must be subjected.

(2) Contractor GSE/PGSE to support the testing along with necessary tools, benches, stands, and handling equipment.

(3) Government facilities for assembly, checkout, and integration testing of ALGMs prior to captive flight testing and launch.

(4) Ranges and range instrumentation compatible with the ALGM and its mission and possessing sufficient flexibility to permit exploration of the performance envelopes in an operational environment.

(5) Test aircraft including using or ALGM carrying aircraft representative of that with which the ALGM will be deployed, chase aircraft for safety and photographic purposes, as well as drones for use until the ALGM rocket motor is man-rated.

(6) Instrumentation pod or an on-board installation to support the captive flight environmental determination effort.

(7) Target simulators, aerial targets, and target compexes for air-to-ground ALGMs.

The foregoing is an abbreviated, but representative, indication of resource requirements for ALGM T&E. Tables II and III reflect the resource and facility requirements for a typical ALGM development T&E program which are beyond those normally available for fabrication,

Environmental Test	Test Item									
	Seeker		Control		ALGM[1]		TD		W&F	Radome
	O	N	O	N	O	N	O	N		
Acceleration										
Captive Carry		X		X		X		X		
Ignition	X		X					X		
Acoustical Noise	X		X					X		
Aero Heating										
Captive Carry	X		X					X		
Free Flight	X		X				X			
Altitude	X		X					X		
Dust		X		X						
EMI					X					
Humidity		X		X				X		
Immersion						[2]X				
Rain						X				
Rain Erosion										X
Salt Fog		X		X				X		
Shock										
Captive Carry		X		X		X		X		
Ignition	X		X		X			X		
Temp. High	X		X		X		X			
Temp., Low	X		X		X		X			
Temp. Shock		X		X		X		X		
Vibration										
Captive Carry	X		X		X			X		
Free Flight	X		X		X		X			
Vibration, Trans.		X		X		X		X		
Hot Gas Tests									X	X
Structural Load.				[2]X		[2]X			X	
Temp./Altitude					[3]X					

NOTES

C = Operating, during part of the test, the test item may be nonoperating.

N = Nonoperating.

1 = Includes Seeker, Warhead, Control, Inert Rocket Motor, unless otherwise specified.

2 = Test to be conducted with dummy missile(s).

3 = Conducted on short round (Seeker, Control, Inert Warhead Sections only).

Figure 14. ALGM Environmental Test Matrix

TABLE II. Government Test Facilities Requirements
(Adapted from Ref. 21)

Base/Center	Facility	Purpose
Naval Weapons Center China Lake, California	Missile Integration Facility (Bldg 31420)	Missile Assembly Test
"	T11 Ground Station (Shrike Assembly Bldg)	"
"	Hangar 3 (NAF)	Aircraft Integration Test
"	MARTS Facility(Bldg.31420)	Seeker/Avionics Tests
"	A-7C Project A/C Data Reduction Facility (Bldg. 31420)	A-7C Data Reduction
"	Missile Assembly Bldg. (Area R Test Facility Area)	Final Missile Integration and Test
"	Echo Range	Captive Flight Test
"	George Range	Captive/Firing Tests
"	NODAC Facility	Data Reduction
"	Range Safety	Command Destruct System Checkout
"	Propulsion Firing Bay	Motor Static Firings
"	Warhead Ranges	Missile/Avionics Integration
"	A-7E Integration Laboratory (Hangar 3)	Missile/Avionics Integration
"	SNORT Facility	Radome Rain Erosion Tests
"	Beacon Shop	Transponder Tests
"	T-Range	Hot Gas Tests
"	Anechoic Chamber (Bldg. 31420)	Seeker Tests
"	Environmental Test Facilities (Michelson Laboratory)	Environmental Testing
"	Analog Simulation Laboratory	Control Section Tests

TABLE II. Government Test Facilities Requirements (cont'd)

Base/Center	Facility	Purpose
Edwards Air Force Base California	Hangar Space	Missile/Aircraft Integ
	Lab Space	Missile Assy Test
	APR-38 Integ Laboratory	Missile/APR-38 Integ
	TM Station	Missile Tests
Naval Air Test Center Patuxent River, Maryland	Launcher Jettison Facility Carrier Qualification Facility	Jettison Tests Carrier Launch and Recovery
Naval Weapons Laboratory Dahlgren, Virginia	Hero Laboratory Warhead Range	Hero Tests Warhead Design Proof Tests
Naval Ordnance Station Indian Head, Maryland	Explosive Ordnance Disposal (EOD) Facility Propulsion Firing Bays Environmental Test Facility	EOD Techniques Motor Qualification Environmental Tests
Naval Weapons Station Yorktown, Virginia	Warhead Loading Facility	Warhead Loading Techniques
Naval Ammunition Depot Crain, Indiana	Environmental Facilities Test Arenas	Fuze Qualification

TABLE III. Government Test Aircraft and Target Requirements (adapted from Ref. 21)

Platform	Purpose
TA-4J Aircraft (B/N 152848)	Missile captive and firing tests
A-7C Aircraft (B/N 156739)	Weapon System captive and firing tests
Chase Aircraft	Missile firing tests, photography
QF-86 Drone	Missile firing tests, FTV-103 (Non-man-rated rocket motor)
F-4G/APR-38 Aircraft	Missile captive and firing tests
A-7E Aircraft (Two Required)	Weapon System captive and firing tests

NWC Simulator Assets for Missile Firings

Expendable targets available at NWCs George Range to support ALGM firings include simulations of:

Targets and Target Complexes

assembly, and test at any qualified ALGM contractor's plant. Additional information with regard to T&E resources, facilities, and funding of these activities are contained in section III F and G and Appendix C of this thesis.

3. Responsibility for and Conduct of Tests

Sections III D and E and V C of this thesis address the subjects of responsibility for tests and conduct of tests, respectively, and provide general information with regard to the roles of the various T&E participants in ALGM development programs. The purpose of this sub-section is to extend the general information mentioned previously to the implementation of the proposed planning strategy for an Integrated Test Program and to suggest the assignment of responsibility to test activities and facilities to conduct the tests for ALGM and major component/ sections. Figures 15 and 16 depict DT&E and OT&E tests respectively, and the test category numbers shown reflect test categories from Figures 8 and 9.

4. Information Flow, Assessment, and Reporting

Section III J of this thesis indicates the relative importance of Information Flow, and Review to Navy T&E programs structured for ALGMs. The Integrated Test Program approach of section V C and the Proposed Test Program Strategy of section VI do not change the historical reporting requirements, responsibilities, or channels of information discussed in those earlier sections. It does change the traditional ALGM T&E approach (e.g., re-orientation of user-evaluator participation and deletion of some TECHEVAL laboratory testing). Thus, the Program Manager and COMOPTEVFOR will still be the focal points for reporting to higher authority within the Navy and OSD regarding DT&E

Test Cat. *	Test Article	Test Resp.	Test Conductor	Facility	Monitor
1	Launcher	Contractor	Gnd Tests - Contractor Flt Tests - GFA	Contractor NWC	OPTEVFOR
2		Contractor	Contractor	Contractor	OPTEVFOR
3		GFA	GFA	NATC, Patuxent	TECHEVAL/OPTEVFOR
4		GFA	GFA	PMTC	OPTEVFOR
1	ALGM	Contractor	Gnd Tests - Contractor Flt Tests - GFA	Contractor NWC China Lake	OPTEVFOR
2		Contractor	Contractor	Contractor	OPTEVFOR
3		Contractor	Contractor Carrier Suit. - GFA	Contractor Carrier Suit. - NATC	TECHEVAL/OPTEVFOR
4		GFA *	GFA	PMTC Pt. Mugu	OPTEVFOR
1	Warhead	GFA	GFA	NWC	OPTEVFOR
2		GFA	GFA	NWC	OPTEVFOR
3		GFA	GFA	NWL, Dahlgren	TECHEVAL/OPTEVFOR
4		GFA	GFA	PMTC	OPTEVFOR
1	Fuze	Contractor	Gnd Tests - Contractor Flt Tests - GFA	Contractor NWC	OPTEVFOR
2		Contractor	Contractor	Contractor	OPTEVFOR
3		GFA	GFA	NAD Crane	TECHEVAL/OPTEVFOR
4		GFA	GFA	PMTC	OPTEVFOR
1	Rocket Motor	Contractor	Gnd Tests - Contractor Flt Tests - GFA	Contractor NWC	OPTEVFOR
2		Contractor	Contractor	Contractor	OPTEVFOR
3		GFA	GFA	NEODF Indian Head	TECHEVAL/OPTEVFOR
4		GFA	GFA	PMTC	OPTEVFOR

NOTES *

1. Engrg. Develop. Tests
2. Component/Part Qual.
3. Contractor Demo. Tests
4. TECHEVAL

GFA - Government Facility/Activity

Figure 15. ALGM DT&E Test Conduct and Responsibility

Test Category	Test Article	Test Responsibility	Test Conductor	Facility	Test Monitor
IOT&E	ALGM System	OPTEVFOR	VX-4 VX-5 Fleet Units	PMTC NWC As Required	None None OPTEVFOR
OPEVAL	ALGM System	OPTEVFOR	VX-4 VX-5 Fleet Units	PMTC NWC As Required	None None OPTEVFOR
FOT&E	ALGM System	OPTEVFOR	VX-4 VX-5 Fleet Units	PMTC NWC As Required	None None OPTEVFOR

Figure 16. ALGM OT&E Test Conduct and Responsibility

and OT&E, respectively. OSD will provide program reports with T&E information to Congress, as required. However, the information resulting from the implementation of the suggested strategy should give increased emphasis to the operational environment while still providing evidence of specification compliance.

Employment of the suggested strategy (sections VI-A 1, VI-A 2, and VI-A 3) should help ensure that appropriate information is available for reporting program status to the DSARC at Milestone II (release to full-scale development), Milestone II A (release to pilot production), and Milestone III (release to full-scale production). The Program Manager can point to the planned program and show progressive achievements relative to the plan and OPTEVFOR's IOT&E evaluations, prior to OPEVAL, should have greater meaning due to the increased emphasis on operationally oriented T&E. The pooled or integrated data base will provide the means to greater visibility for all program participants and reviewers, of problems that have occurred, steps taken to rectify the problems, and the effectiveness of the corrective action. This increased user-evaluator participation throughout the T&E program, the plan for and adherence to the progressive attainment of ALGM performance and reliability goals/requirements, and the increased problem identification and corrective action visibility should enhance the ALGM T&E program credibility in the eyes of DD(T&E) and other reviewers. The resulting T&E information should be especially important and useful to DD(T&E) when evaluating and making his assessment of the ALGM T&E program to the DSARC.

B. ALGM T&E ASSESSMENT

1. Impact of New Requirements and Guidelines

Several T&E efforts associated with recently developed ALGMs were examined to assess the impact of the new requirements and guidelines. Unfortunately, most of the programs were already under development by contractors when the new requirements and guidelines were promulgated, and, as a result, many deficiencies which might otherwise have been avoided have occurred, necessitating redesign, rework, and retest efforts. All of the foregoing obviously add to the ALGM development cost and lengthen the schedule.

a. AIM-7F

For example, the AIM-7F failed OPEVAL I in 1972 which resulted in a major redesign encompassing 60% of the existing modules. Subsequent to the redesign, the T&E effort was not significantly restructured from its predecessor (i.e., still performed to old T&E requirements), and a building block approach to missile qualification was not followed. The mission profiles had been found to be inadequately defined and the specifications and required testing did not reflect the operational environment in which the AIM-7F was to perform. Inadequate planning for T&E and poor coordination among T&E participants resulted in severe laboratory environmental test failures and failure attributed to inappropriate environmental conditioning caused ALGM flight failures.

OPEVAL II was held in 1974 and AIM-7F did not pass because captive flight MTBF, while improved, was still not adequate and design specifications for successful guidance were not achieved. In fact, many of the same problems which occurred in OPEVAL I were repeated in OPEVAL II indicating the intervening redesign and T&E effort preceding OPEVAL was ineffective. If the contractor DT&E and TECHEVAL effort had been

properly planned, coordinated, and implemented, most of the deficiencies would probably have been corrected prior to OPEVAL.

A follow-on version of the AIM-7F is now under development. As a result of the preceding deficiencies, the Congressional Armed Services Committees have taken a very specific and direct interest in this ALGM's T&E, inserting the following language in the FY 1977 appropriations bill,

> "The Navy and Air Force are advised to insure a viable test program for the monopulse missile that will clearly demonstrate the ability of this missile to perform in an operational combat environment. The Director, Test and Evaluation, is to provide a report to the Committee on Armed Services at the conclusion of the advanced development phase that describes the test plan, the environment (electronic countermeasures, etc.), the test conditions, and the test results and evaluations" [Ref. 22].

b. AGM-78D

The AGM-78D Standard ARM ALGM presents a somewhat better picture than the preceding due to the implementation of an improved T&E program embodying many of the new T&E requirements. Prior to the "D" version, Standard ARM missiles had been subjected to a limited, poorly planned and executed T&E effort. ALGM specifications were inadequate (in fact were based on the shipboard Standard Missile) and requirements were not stated in operational terms (i.e., did not reflect either the physical or tactical environment). Qualification of components, which was seldom performed, was to inappropriate specifications. The DT&E effort provided poorly for design data feedback and was characterized by poor failure analysis and reporting. Contractor Demonstration Tests (CDTs) were performed for information only, and there was poor follow-up and little corrective action when failures occurred. There was little or no coordination between the T&E participants; consequently, when

TECHEVAL was performed, ALGMs were overstressed and failed due to misinterpretation of the missile specification and lack of a detailed test plan and procedure. Captive flight evaluations and ALGM launches exhibited execution problems and results were controversial. OPEVAL results were similarly controversial and the missile failed to meet acceptable standards resulting in a recommendation to the CNO that the AGM-78B and C not be deployed. They were deployed, however, because of conditions in southeast Asia.

The AGM-78D program, with strong leadership from the Navy Program Manager and his participating field activity Technical Manager, developed and implemented an improved T&E program starting in 1972 along with the redesign effort. A mission profile was jointly developed by the Navy and the contractor based on flights simulating tactical missions with partially instrumented ALGMs, and the ALGM specifications were modified accordingly. The building block approach to component, assembly, section, and ALGM qualification was employed culminating with a formal First Article Approval Demonstration Program where environmental and reliability demonstration under simulated mission conditions occurred. The Navy TECHEVAL agency and the Air Force Test and Evaluation Command to perform an OPEVAL type of test called AFEVAL (under a joint test agreement in which OPTEVFOR did not participate) were involved in the DT&E planning and monitored the Contractor Demonstration Tests.

The TECHEVAL was planned and executed by the TECHEVAL agency without OPTEVFOR participation. Asset and funding limitations were present but the TECHEVAL agency performed some repetition of the Contractor Demonstration Tests (i.e., laboratory environmental and ground reliability tests). Resource problems related to range instrumentation

and target availability were evident, but the results of the captive flight and launch performance and reliability evaluations confirmed compliance with the specifications. The results of the captive flight reliability evaluation and the contractor simulated captive flight reliability demonstration were remarkably similar.

The AFEVAL, planned and conducted by the Air Force under the joint test agreement, exhibited results similar to TECHEVAL. Some problems related to ground handling and Peculiar Ground Support Equipment were encountered and operational testing flexibility was limited by the necessity to use Research and Development ranges and a shortage of some resources, but ALGM operational effectiveness and suitability were demonstrated.

The foregoing is a classic example of the situation where we never have enough time and money to conduct a T&E program properly the first time but always seem to be able to find the time and money to do it a second, third, and even a fourth time.

2. Post OPNAVINST 3960.10

Currently, there is an ALGM development program underway that has the opportunity to develop and implement a T&E program in accordance with the new directives and guidelines of section III. The AGM-88 HARM (High-speed Anti-Radiation Missile) is currently in advanced development and has a system integration contractor under NAVAIR contract. A development specification has been prepared with performance and reliability requirements specified in terms of mission conditions. An extensive T&E planning effort has taken place with considerable effort on the part of the Navy Program Manager and the other T&E participants to develop a TEMP in accordance with the requirements of OPNAVINST 3960.10.

Examination of the HARM preliminary TEMP [Ref. 14] reveals that the planned T&E program is moving in the direction of the Integrated Test Program proposed in this thesis. Positive indications are extensive participation of all T&E participants in the planning of the T&E program and integration of IOT&E into the DT&E effort by having OPTEVFOR (VX-5) as the operator in a significant number of captive flights and ALGM firings. OPTEVFOR has monitored all advanced development firings and participated in all design reviews and Integrated Logistic Support Planning conferences as has the TECHEVAL activity. A mission profile has been developed and is being confirmed by an environmental determination effort consisting of captive flights with instrumented missiles followed by laboratory evaluation. The mission profile is being used to structure the simulated captive flight environment for the reliability growth test effort beginning in the engineering development phase and continuing through prototype development. A preliminary view of the growth test plan has been presented to NAVMAT and DDR&E (during a management review) and was found acceptable.

During the prototype development phase of full-scale development, hardware and aircraft installations will be shared by DT&E and IOT&E. Contractor Demonstration Tests for specification compliance are planned for this period including laboratory demonstration of captive flight reliability.

The TECHEVAL will be conducted utilizing pilot production ALGMs. The current TECHEVAL plan includes ground chamber performance and reliability testing as well as captive flights to confirm specification compliance. There will also be an extensive supportability evaluation. The reliability testing (ground chamber and captive flight) will be to

demonstrate the required specification minimum acceptable MTBF at the 90% confidence level.

OPEVAL will include joint Navy/Air Force testing to examine operational effectiveness and suitability. OPTEVFOR will conduct a captive carry reliability evaluation and will pool OPEVAL data with previous DT&E/IOT&E data in this assessment. Approximately 1000 hours of ALGM captive flight operation is planned during the joint testing effort.

In summary, the AGM-88 HARM ALGM T&E program approaches the proposed Integrated Test Program of this thesis. However, the HARM program diverges from the Integrated Test Program by the TECHEVAL planned conduct of environmental tests and TECHEVAL will apparently not pool its data with contractor and other DT&E/IOT&E data. OPEVAL test data will be pooled, as previously mentioned, but a significant number of ALGM operational hours are to be acquired committing significant numbers of ALGM assets, range facilities, aircraft, and necessary support personnel for an extended period of time.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Consideration of the Navy's ALGM T&E requirements, management problems, and alternative approaches to ALGM T&E management leads to the following major conclusions:

1. The successful outcome of the T&E program is largely dependent upon the managerial ability of the Program Manager to coordinate the diverse activities and resources all of which are not under his direct control.
2. Excessive duplication exists in testing performed by major participants in the Navy ALGM T&E process.
3. Operational test and evaluation agencies do not participate adequately in early T&E planning.
4. Although still a relatively new requirement, preparation and implementation of TEMPs for some ALGMs and other air weapon systems are lagging behind program development schedules and OPNAVINST 3960.10 guidelines.
5. A number of high level panels and commissions have performed studies of T&E over the past decade and have made similar recommendations for improvement of the process and its management. While policy changes have been made, many of the management, resource and operational problems remain.

Other significant conclusions are:

1. Appropriate test design utilizing statistical design of experiment techniques is not being utilized by ALGM T&E participants

resulting, in some cases, in excessive and inefficient testing as well as improper interpretation and utilization of test data.

2. Lack of definition of or delay in defining ALGM mission profiles leads to improper and often inadequate testing of ALGMs.
3. Central management of NAVAIR T&E activities needs to be strengthened to reduce costly duplication of facilities and capabilities among the Navy's Major Range and Test Facility Base for air weapons.
4. Program Managers may be at a disadvantage when attempting to resolve, with COMOPTEVFOR, testing requirements reflected in the TEMP because of their relative positions with respect to CNO.
5. OPTEVFOR is dependent upon the Program Manager for most of its IOT&E funding and resources; therefore, the structure of the OT&E effort may be adversely affected.
6. OPTEVFOR needs to supplement its capabilities and resources to include analytical and technical expertise in order to meet its increasing testing responsibilities. This is especially true if the trend toward increased simulation and reduced expenditure of ALGM assets continues as a result of time and funding constraints.
7. Software is given insufficient emphasis in early program phases, as no standard DoD procedure for T&E of software items exists.
8. Unplanned reviews and requests for ALGM T&E data or additional tests by those concerned with program review and oversight affect program schedules and impact discretionally funds.

B. RECOMMENDATIONS

1. T&E for new Navy ALGMs (ACAT I and II Programs) should be based on the Integrated Test Program approach as presented in this thesis.
2. Early T&E planning as recommended in the "Proposed Test Program Strategy" should be emphasized on programs such as Short Range Air-to-Air Missile (SRAAM) and Medium Range Air-to-Air Missile (MRAAM) which are in advanced development.
3. The Navy should pursue the idea of utilizing the skills of Navy Laboratories to support OPTEVFOR. The laboratories can provide the stability and continuity of personnel possessing appropriate technical expertise.
4. NAVAIR should take steps to improve the timely communication, flowdown, and implementation of new T&E directives and guidelines.

APPENDIX A

Organizations with which Interviews were Conducted

1. Office of the Secretary of Defense, Washington, D. C.

   DDR&E(T&E)

2. Office of the Chief of Naval Operations, Washington, D. C.

   OP-983

3. Headquarters Naval Material Command, Washington, D. C.

   MAT-08

4. Naval Air Systems Command, Washington, D. C.

   AIR-06
   AIR-620
   AIR-242

5. Operational Test and Evaluation Force

   Headquarters, Norfolk, Va.
   Air Development Squadron Five

6. Naval Weapons Center, China Lake, Ca.

   Code - 06
   Code - 07
   Code - 35

7. General Dynamics Corporation, Pomona Division, Pomona, Ca.

   Director of Defense Suppression

APPENDIX B

Descriptions of DT&E, OT&E and PAT&E [Ref. 4]

1. Development Test and Evaluation (DT&E)

DT&E is primarily that test and evaluation planned, conducted, and monitored by the developing agency of the DoD component to demonstrate that the engineering design and development process is complete, that the design risks have been minimized, that the system will meet its performance specifications, and to estimate the system's military utility. DT&E includes testing of components, assemblies, sub-systems, software, hardware/software integration, and advanced development and full-scale system level tests under various environmental conditions. Also tested is compatibility and interoperability with existing or planned equipments and systems.

2. Operational Test and Evaluation (OT&E)

OT&E is that test and evaluation conducted to esimate the system's military utility, operational effectiveness (including survivability and vulnerability), and operational suitability (including compatibility, availability, interoperability, reliability, maintainability, human factors, logistic supportability and training requirements) as well as the need for any modifications. In addition, OT&E provides information on organization, personnel requirements, doctrine, and tactics. It may also provide data to support or verify material in operating instructions, publications. and handbooks. OT&E will be conducted in as realistic an operational environment as possible. OT&E is divided into two major parts: Initial OT&E (IOT&E), which is defined as all OT&E

prior to the first major production decision; and follow-on OT&E (FOT&E), which is all OT&E after the first major production decision.

3. Production Acceptance Test and Evaluation (PAT&E)

PAT&E is test and evaluation of production items to demonstrate that the items procured fulfill the requirements and specifications of the procuring contract or agreement. It is the responsibility of each DoD component to accomplish the necessary PAT&E throughout the production phase of the system life cycle.

APPENDIX C

Facilities for T&E of Navy ALGM [Ref. 5]

1. Naval Ordnance Missile Test Facility, White Sands, New Mexico

Its mission is to support the Navy guided missile and rocket programs including ground and flight testing and to participate in the operation of the DoD integrated missile test range at White Sands, a major national range. This activity reports to CDR, NAVSEA.

2. Naval Air Test Center, Patuxent River, Maryland

Its mission is to coordinate and perform T&E of aircraft weapons systems, their components and related equipment, conduct test pilot training, and provide technical advice and assistance to NAVAIR, contractors, etc. This activity reports to CDR, NAVAIR.

3. Pacific Missile Range, Point Mugu, California

Its mission is to provide range support for DoD and other designated government agencies for launching, tracking and collecting data in guided missile, satellite and space vehicle research development evaluation and training program and actual operations. This activity is a national range and reports to CDR, NAVAIR.

4. Naval Weapons Center Ranges, China Lake, California

Its mission is to provide ground ballistics, aircraft, explosive testing and supersonic track ranges for testing (R&D) the performance of fuzes, bombs, free-fall weapons, rockets, guided missiles, and other ordnance under actual operational conditions. This activity is part of a Navy in-house laboratory.

5. Naval Missile Center, Point Mugu, California

Its mission is to perform test, evaluation, development support and exercise engineering cognizance as assigned of naval weapons, weapon systems and related devices. This activity reports to CDR, NAVAIR.

6. Naval Weapons Laboratory Ranges, Dahlgren, Virginia

Its mission deals primarily with testing of Navy guns and mounts, although testing of some missile components also occurs. The range testing is subdivided into two broad categories; proof and acceptance testing, the object of which is to assure the quality, performance, safety and reliability of ordnance for the fleet; and developmental testing, the objective of which is to provide an experimental basis for new and improved weapons and systems. This activity is part of a Navy in-house laboratory.

7. Naval Explosive Ordnance Disposal Facility, Indian Head, Maryland

Its mission is to conduct RDT&E in technical matters for explosive ordnance disposal and render safe procedures for conventional and special weapons, guided missiles, biological and chemical munitions, equipment, both U.S. and foreign. This activity reports to CDR, NAVSEA.

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